national Conference on Marine Bioinvasions

vaders: agents of change in a changing world

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T BOOK

by: Portland State University, The International Conference for the Exploration of the Seas (ICES), acific Marine Science Organization (PICES), Pacific State Marine Fisheries Commission, eanographic and Atmospheric Administration (NOAA), National Sea Grant, and the PSU/SERC nvasions Research and Policy Institute

9 July 2009

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The confereoce agenda promises to be an exciting one , wit-h interesting talks, posters, and specia1sessio There wiU a!s0 be opportunities to nerwork and informaUy exchange infotmation with yow-colle¡igucs. hope that the conference will províde you a greater aware.ness of the rece nt progress in understandíng an managing coastal and marine bioinvasions as well as the challenges that; wea.re still facing.

In the spirit of sustainabilíty w e have worked with the caterer to millimize discards, compost food waste to recycle co nt ainers. Thank you for your understanding of our commitment to protecti11g the enviromn and our decision to not offer you a tote bag or e>ther trú1kets. 1 recognize that these are small steps, but P and the meeting organizers are s triving to reduce our carbon footp rint . The Steering Committee would appreciate your suggestions on further improvemen ts for future conferences.

Once aga.in, ,vckome to Portlancl, Oregon and to the 6[1h] lnternational Conference e>11 Marine 8ioinvasio 1 hope that you havc a stimulating and rewa.rcling experience.

Mark D. Sytsma
Conference Coordinato r
PSU/SERC Aquatic Bioim·asion Researdt and Policy lnstitut e

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Table of Contents

DIETARY HABITS AND FEEDING ECOLOGY OF INVASIVE LIONFISH IN THE TROPICAL WESTERN ATLANTIC

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Oral Presentation

The invasive Indo-Pacific lionfishes (*Pterois miles* and *Pterois volitans*) are now widely distributed along the U.S. East Coast, Bahamas, and the Caribbean. It is anticipated that lionfish will impact native reef fish communities via competition for dietary resources. To investigate lionfish feeding habits in the tropical western Atlantic, we analyzed approximately 1200 lionfish stomachs sampled from various locations on the Bahamian archipelago. Our results suggest that lionfish diet is approximately 78% finfish and 15% crustaceans by percent volume. When considering the composition of finfish, we found that lionfish feed on over 20 families of fishes with the top five most important families comprising Gobidae, Labridae, Grammatidae, Apogonidae, and Pomacentridae. Of the crustaceans, we found that lionfish feed primarily on shrimps. Lionfish are considered ambush predators frequently using their large pectoral fins to corral prey. Lionfish feeding occurs primarily during the crepuscular periods of the day with peak feeding occurring during the early morning hours. The composition of finfish in lionfish diet increases at approximately 140 mm total length corresponding with the onset of sexual maturation. These results provide the first comprehensive assessment of lionfish dietary habits in the Atlantic and their native range and provide a quantitative analysis of the impacts lionfish will have on forage fishes of Atlantic reef fish communities.

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EARLY DETECTION ANO RAPID RESPONSE LIONFISH WORKSHOPS IN THE INVADED WESTERN ATLANTIC

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Oral Presentation

Indo-pacific Lionfish *(Pterois volitans* and *Pterois miles)* have recently invaded western Atlantic waters, representing the first successful marine fish invasion in the region. Spread of this invasion is occurring ata rapid pace through the northern Caribbean and is on course to establish through the entire tropical region in a matter of years. Few if any natural predators have been identified as potential controlling factors and impacts of this invasion are beginning to be realized as severe. In efforts to increase awareness and implement rapid response and control in invaded and soon to be invaded areas, the Reef Environmental Education Foundation (REEF) in close partnership with NOAA, the USGS, Simon Fraser University and others have been conducting in-country lionfish workshops to build capacity and increase awareness. These workshops have been tailored to the specific country needs and include talks to the general public, hands-on collecting and handling workshops for dive industry professionals, medical information serninars and detailed work with in-country resource managers to help build national lionfish response plans and monitoring efforts. To date, over 40 talks and workshops have been held in the Bahamas, Bermuda, Turks and Caicos, Cayman Islands, Bonaire and the Florida Keys. Here we will highlight these efforts and focus on future plans and directions for establishing a region v,,jde network for early detection and rapid response.

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EFFECTS OF THE INVASIVE íNDO-PACIFIC LIONFISH ON BAHAMIAN CORAL REEF FISH CO MMUNITIES: PREDAT LON AND CO MPET JT fON

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O ral Pi-esenta ,tio n

The Indo-Pacific lionfüb *(Pr.erois volitans)*, lntro<luced to Florida waters in the early 1990s, is sprea:cl.ing rapiclly througbout the Cnrihbean region . This invas.ive predator tnay aITect coral -reef ecosystems 1•ia predation on native fishes and invertebrates, as well as competition with native predators. Previous experiments bave shown that l.ionfisb bave a strong negative effect, presumahly Jue to predation, ou th number of native coral-reef füh recruiting to small patch reefs in the Bahamas. 1 conductecl a field e..xpe.riment on a matrLx of small patch reefs to (1) compare the effect of lionfüb on the recnüt commun to the effect of an ecologically similar native plscivore, the eoney grouper, (2) to dctem1ine the combin dfoct of the in\'asíve piscivore and the native piscivore on recruit communities, allCI (3) to determine whether lionush are competi:ng with caney grouper for prey resources. Single Hon1lsh transplanted ont small patch reefs caused sigruucant 1·eductions in rec ruit ment o!'native fishes-hy an es tim ate cl 85% over eight week.s. In comparison, simila.rly sized native coney grot1per rransplanted onto patch reefs reduced recruitnient by an average of 35% over the same period. The combiaed effect of a single li<Jllhshan<l a sing le coney grouper was not significanLly greater tban thc effect oflion.Bsh alone, and resulted in an 88 average reduction in recr uitme n.t. Líonfish also c:a 1se<l a significant reduclion in pccies richness hy an average of 34%, wh.ile coney grouperreduced richnessby approximately 23%, and both predators tog reduced richne s by 42 %. [n a<ldition, multivariale analyses <lemonstrat e that the two predators have si eITects on the overall recruit community, although lionfisb have a stronger effcct on a larger set of spcc

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SITTING ON THE DOCK OF THE BAY: PATTERNS OF NATIVE ANO INVASIVE DIVERSITY IN SAN FRANCISCO FOULING COMMUNITIES

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Oral Presentation

Coastal ecosystems currently represent one of the most invaded systems on the planet, and a high proportion of invasive species have successfully established within fouling communities in bays and estuaries worldwide. We explored patterns of native and non-indigenous alpha-diversity (diversity within a community), gamma-diversity (landscape or regional diversity) and beta-diversity (species turnover or change in species composition from site to site; gamma/ alpha) in marine fouling communities within San Francisco Bay, CA. We surveyed replicate three month old fouling communities (n=20) and identified diversity in ten sites across the bay during multiple summers (2000, 2001). A subset ofthese sites was re-surveyed intensively in 2006, 2007, and 2008. General trends indicate that native alpha-diversity was consistently low and did not correlate with non-indigenous alpha-diversity. In contrast, native beta-diversity was high in comparison to non-indigenous beta-diversity. When the effect of dominant species (mostly solitary tunicates such as *Ciona intestinalis, Ciona savi9nyi, Styela clava,* and *Ascidia zara)* on diversity was considered, decreases were seen in alpha-diversity and beta-diversity. The effect of dominant species in this system may have a stronger influence on overall community diversity at both local and regional scales.

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PRIORITIES FOR RESEARCH ON THE DETECTION AND CONTROL OF INVASIVE SEAWEEDS: RESULTS OF 2008 ASILOMAR WORKSHOP

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Oral Presentation

Infestations of non-native marine algae (seaweeds) and non-native marine flowering plants have increased dramatically over the past 20 years in the world oceans and US coastal and estuarine ecosystems (Botanica Marina Vol 50, 2007; Williams and Smith 2007. An. Rev. Ecol. Evol. Syst.38:327-3359). The most well known example is the incursion of the green alga *Caulerpa taxifolia* along the coasts of seven Mediterranean countries beginning in the 1984, which spread to more than 40,000 acres. The 2000 infestation of C. *taxifolia* in California was successfully eradicated by 2006, but the cost was over $7 million. Hawaii has also experienced increases in nuisance marine algae, sorne of which threaten the fragile corrals and their delicate ecosystems. Marine algae and marine plant invasions can interfere with near-shore oyster production; fish and invertebrate diversity and can also introduce toxins in the food web. There are no US-EPA registered products for management marina algae or marine angiosperms except for the use of"Habitat" (imazapyr) to control *Spartina alterniflora* (and hybrids) on the W est Coast of the US. Moreover, in contrast to a long history and well-focused research effort directed to management of freshwater weeds there are no similar research programs aimed at development strategies and methods for these marine invaders. Results of a workshop held in 2008 suggest that there is sorne consensus on both target species priorities and on research areas for improved detection and control. Sorne of the highest ranked species (i.e. in most need of control research) include: *Caulerpa* spp, *Codium* spp., *Gracillaria* spp., *Kappaphxcus* spp., *Sar9assum* spp., *Undaria* spp., and *Zostera Japonica.* Research on life cycles, potential herbicide susceptibility and remate sensing were also deemed high priority. The information from this workshop points to the urgent need to develop of inter-agency and prívate partnerships research programs that can lead to safe and effective early detection and control methods far marine macro algae and flowering plants. This effort could be accomplished by relatively moderate redirection and augmentation of research programs at existing marine and estuarine research facilities in the US and elsewhere. Effective technology transfer from fresh water weed control strategies to invasive seaweeds, coupled with new research could provide desperately needed tools far detection, rapid response and management of invasive seaweeds.

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PAST EXPERIENCE PREDICTS FUTURE SOURCE REGIONS OF MARINE NON-NATIVE SPECIES

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Oral Presentation

Effective management strategies are needed to curb the increasing frequency of introductions of marine non-native species. However, current models are limited in their ability to reliably explain large amounts of variation in the outcome of biological invasions across taxa, locations and modes of inquiry. While detailed models are necessary to target specific species which pose a prominent threat, more general rules can be used to inform larger prevention measures. We adopt the theory that invasion pattems result from variation in characteristics of source and recipient environments that prevent or facilitate survival and establishment of non-native species. Building on this, we suggest that the number of species shared between two regions can be used to predict the likelihood of future introductions of species between those same regions. Using distribution and introduction records from the past 200 years, we demonstrate that the source ofhistoric species introductions can be used to predict the source locations of 90% of future introductions to the U.S. For North America, matched regions include areas of North-East Asia and North-West Europe. More species should be expected from these locations and management strategies should be directed at vectors acting from them.

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THE EFFECTS OF DIDEMNUM VEXILLUM OVERGROWTH ON MYTILUS EDULIS filOLOGYANDECOLOGY

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Oral Presentation

Didemnum vexillum is an invasive tunicate that has been observed overgrowing severa! species of sessile marine animals, including the common blue mussel *Mytilus edulis.* It is clear that this overgrowth negatively affects the retrieval and processing of farmed mussels. However, the effects of overgrowth on mussel biology have not been extensively quantified. Therefore, this study aims to compare growth, reproduction, and predator preference for mussels not covered by D. *vexillum,* and those that are overgrown. Mussels are maintained in triplicate cages at the University of New Hampshire pier in Newcastle, NH, where D. *vexillum* is a dominant fouling species. Each month, thirty mussels from each set of cages are measured for height, length, and width. Every three months for a year, a set of each clean and overgrown mussels are retrieved and measured in the lab to calculate shell thickness index, tissue index, lip thickness, and reproductive output (measured by gonad weight and from histology samples). From the first two sets of data, it is evident that D. *vexillum,* when healthy and thriving in the late fall (November 2008), may cause a decrease in *M. edulis* tissue index and lip thickness. When the tunicate enters a senescent period during the winter (February 2009), it appears to have no effect on the mussel. In both November 2008 and February 2009, there was no difference in shell thickness. This presentation will also cover results from the remaining trials in the growth experiments, as well as the results of our other experiments testing the effects of this epibiosis completed during Summer 2009.

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DISPATCHES FROM AN INVASION FRONT: DOES WATER TEMPERATURE DETERMINE THE OUTCOME OF AN ECOLOGICAL ARMS RACE BETWEEN AN INTRODUCED CRAB AND ITS ARMORED PREY?

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Poster Presentation

Phenotypic plasticity is the expression of different characteristics by a genotype in response to environmental cues. Phenotypic plasticity may play an important, but unappreciated; role in biological invasions. For example, induced defenses mounted by native prey might deter an introduced predator, or alternatively, rnight be countered by reciproca! modification of the invaders' trophic (i.e., feeding) structures. Background environmental cues, such as water temperature, may also influence the magnitude of phenotypic responses by both predator and prey. The goal of this study was to examine how colder temperatures at the northem front of an invasive predator's range influence reciprocal responses between predator and prey. In the northwest Atlantic Ocean, the introduced European green crab *Carcinus maenas* encounters latitudinal differences in shell thickness of its snail prey *Littorina obtusata* and in water temperature. Previous experiments have shown that *L. obtusata* responds to the presence of C. *maenas* by laying do,vn thicker shell, and C. *maenas,* in tum, responds to better-defended snails by developing a relatively larger crusher claw. Colder water temperatures characteristic of northern Maine, however, appear to suppress claw responses to shell thickness. Snails at these colder latitudes tend to have thinner shells than their warmer water counterparts. To look for correlated phenotypic patterns between predator and prey populations, we surveyed C. *maenas* and *L. obtusata* populations over narrow temporal and spatial scales. In summer 2005, we conducted monthly surveys at six rocky intertidal sites along 30 km of the northern Maine coast. We observed strong variation in snail shell thickness among sites and over the season that correlated with crab density. However, at these same scáles, we detected no significant temporal or spatial variation in relative crab claw height or any correlation with snail shell thickness. These patterns suggest that at colder temperatures, snails can modify their armor in response to signals that correlate with risk, but that crabs are unable to respond to the changes in snail shell thickness. Our results point to the importance of considering background temperature when predicting C. *maenas* range expansion or ecological impacts. As ocean temperatures warm in this region, we would expect C. *maenas* to be released from temperature constraints and have greater impact on snail populations.

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THUNNUS ALBACERES

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Oral Presentation

Lcngth-weight relationship and relative condition factor (Kn) of migratory yellow fm tuna, *Thunnus albaceres* from Pakistaní waters, were studied from 850 specimens ranging from 475 to 1957 mm in total length and 1500 to 119226 gin weight for the period of one year starting from October 2005 to September 2006. The prcsent study was conducted through the fishing vessels named Long liner, Anda 747 and Xhigi. Length - weight relationship is shown by the following equation: log W= -3.68+ 3.88LogL. The relative condition factor (Kn) was determined, the mean (Kn) for the experimental fish was found to be 1.05. The length-weight relationship and relative condition factor showed that the growth of yellow fin tuna *Thunnus albaceres* was found to be ideal (b= 3.88) in the population that migrates in deep sea from Pakistaní waters.

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CAN OCEAN CONDITIONS PREDICT RECRUITMENT STRENGTH OF THE INVASIVE EUROPEAN GREEN CRAB, CARCINUS MAENAS?

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Oral Presentation

Once a non-native species arrives and survives in an area, its persistence depends on its recruitment success. If conditions are not favorable for recruitment it will become extinct. The European green crab *(Carcinus maenas)* has a six-year life span and has persisted at low densities in Oregon and Washington coastal estuaries for the past 11 years. We show here that after the arrival of the strong founding year class of 1998, significant self-recruitment to the Oregon and Washington population occurred only in 2003, 2005 and 2006. Warm winter water temperatures, high Pacific Decadal Oscillation and Multivariate ENSO Indices in March, late spring transitions and weak southward shelf currents in March and April are correlated with the arrival of these st::rong year classes. Cold winter water temperatures, low Pacific Decadal Oscillation Indices, early spring transitions and strong southward (and offshore) currents in March and Apríl are linked to year class failure. The winter of 2008 was especially cold with water temperatures never rising above 10ºC. Since green crab larvae cannot develop below 10ºC, virtually no recruitment occurred in Oregon and Washington in that year. Right now, green crabs are still too rare to exert a measurable effect on the native benthic community and on shellfish culture in Oregon and Washington. However, if their numbers were to increase, we would be able to predict the arrival of strong year classes from ocean conditions and alert managers and shellfish growers of possible increases in predation pressure from this invader.

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DOES THE INTRODUCED EUROPEAN GREEN CRAB, CARCINUS MAENAS, CONSUME MORE PREY THAN NATIVE DUNGENESS, CANCER MAGISTER?

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Oral Presentation

The prey consumption rates of two estuarine crab species were compared: native Dungeness, *Cancer ma9ister,* and introduced European green crab, *Carcinus maenas.* Similar sized crabs of each species were placed into individual cages and submerged in seawater. Each crab was offered a known number of the standard-sized mussels *(Mytilus trossulus),* or native oysters, *(Ostrea lurida)* and the number of consumed prey items was recorded. When offered soft-shelled mussels, sub-adult *Cancer ma9ister* ate more prey per day (7. 2 mussels) than adult *Carcinus maenas* (5. 2 mussels) of similar size. However, when crabs were offered harder-shelled native oysters, *Cancer ma9ister,* with their delicate claws, were less likély to crush them than *Carcinus maenas* with their more robust crusher claws. While *Carcinus maenas* is competitively dominant to similar sized juvenile *Cancer ma9ister,* their per capita feeding rate would depend on prey type._

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EARLY LIFE STAGE BIOLOGY OF A NEW PO PULATION OF GREEN CRAB CARCINUS MAENAS IN PLACENTIA BAY AND IMPLICATIONS FOR MUSSEL CULTURE IN NEWFOUNDLAND

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Poster Presentation

Following the discovery of Green crab *Carcinus maenas* in Placentia Bay Newfoundland in August 2007 there has been concem for the aquaculture industry. Blue mussels are not only a desired prey species for green crab; it is also a very important protective habitat for early life stage C. *maenas.* (Hedvall et al.1998). Thiel and Demedde 1994 state that juvenile C. *maenas* are in high densities ·within mussel beds in the Wadden Sea immediately after larval settlement and they are small enough to hide effectively between mussels. If this is true for other green crab populations mussel seed transfers from Placentia Bay could provide a vector for larval transfer to the Green Bay where provincial mussel aquaculture is concentrated. Work was conducted to determine size at maturity by GSI to further understand reproductive biology which will be used in further larval experimentation in relation to mussel seed management. Preliminary results show that this population sexually matures at a smaller carapace width than warmer populations and are active at less than previously thought tolerable water temperatures for this species. Further research plans include holding and inducing larval release of ovigerous females, larval rearing and rnitigation techniques.

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DIFFERENTIAL ESCAPE FROM PARASITES BY TWO COMPETING INTRODUCED CRABS

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Oral Presentation

Although introduced species often interact with one another in their novel communities, the role of parasites in these interactions remains less dear. We examined parasite richness and prevalence in two invasive shorecrab species with different invasion histories and residency times in an introduced region where their distributions overlap broadly. On the northeastern coast of the US, the Asian shorecrab, *Hemi9rapsus san9uineus,* was discovered 20 years ago, while the European green crab, *Carcinus maenas,* has been established for over 200 years. We used literature and field surveys to evaluate parasitism in both crabs in their native and introduced ranges. We found only one parasite species infecting *H. san9uineus* on the US East Coast compared to six species in its native range, while C. *maenas* was host to three parasite species on the East Coast compared to ten in its native range. The prevalence of parasite infection was also lower for both crabs in the introduced range compared to their native ranges; however, the difference was almost twice as much for *H. san9uineus* as for C. *maenas.* W e discuss explanations for the greater parasite diversity in C. *maenas* in the US, as well as implications of our results for interactions between the crab species and potential community-wide effects.

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PUTTING PARASITE RELEASE INTO PERSPECTIVE: A BIOGEOGRAPHIC EXAMINATION OF PARASITES ANO HOSTS ACROSS THEIR NATIVE ANO INTRODUCED RANGE

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Poster Presentation

While biogeographical patterns have been explored in host species introduced to new populations, such patterns are less apparent in hitchhiking parasites carried with hosts. Furthermore, the effect that invasion pathways have on parasite biogeography also remains unclear. Therefore, we explored parasite and host biogeography in two invasive snail hosts, which were introduced to the US west coast from similar regions on the US east coast; however, these hosts possess very different invasion histories. The first host, *Ilyanassa obsoleta* (eastem mudsnail), is believed to have been accidentally introduced to the west coast in the late 1800's with intentional introductions of the Eastern Oyster (*Crassostrea 1ir9 ini ca),* which tapered off significantly by the 1930' s and is now an effectivel y closed vector. The second host, *Littorina saxatilis* (rough periwinkle snail), was accidentally introduced with the Maine baitworm trade, which ships live baitworms packed in intertidal seaweed to other locations around the globe, notably San Francisco Bay, which is where *L. saxatilis* was first observed on the west coast in the 1990s (and introductions continue today). Both snail hosts are parasitized by several different species of trematode in their native regions, and a few of these parasites have been found infecting the snails in their introduced populations on the west coast. We explored differences in trematode richness and prevalence among snail populations in the native region, the source region, and the introduced region and found significant differences between the tvvo invasive snails, specifically related to their different invasion vectors/pathways. Moreover, we performed logistic regression analyses to determine the factors (e.g., native prevalence, source prevalence, native latitudinal range, host taxonomy, time since introduction, etc) that most significantly explained the parasite patti:ms we observed in the introduced region. We found that specific native and source region attributes can explain biogeographical patterns observed in introduced populations and that invasion pathways also appear to affect these patterns in parasites on the west coast.

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INTEGRATION OF AN INTRODUCED CONSUMER INTO AN ESTUARINE FOOD WEB: DIRECT ANO INDIRECT EFFECTS OF THE NEW ZEALAND MUDSNAIL IN THE COLUMBIA RIVER ESTUARY

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Oral Presentation

Introduced species interact with recipient communities via direct and indirect interactions. The New Zealand mudsnail *{Potamopyr9us antipodarum)* can achieve high densities in invaded systems, potentially causing negative effects on native consumers and their predators. New Zealand mudsnails are increasingly found in bays along the Pacific Coast of North America but there are few studies of the interactions between mudsnails and native species in estuarine systems. I examined interactions between Ne Zealand mudsnails, the amphipod *Americorophium salmonis,* and the isopod *Gnorimosphaeroma insulare,* in the presence of native predators including Pacific staghom sculpin *(Leptocottus armatus),* threespine stickleback *(Gasterosteus aculeatus),* juvenile starry flounder *(Platichthys stellatus),* and signal crayfish *(Pacifastacus leniusculus).* Results from thls laboratory experiment show that while all predator species consume mudsnails, crayfish consume significantly more snails than do fish. In addition to this direct effect, mudsnail presence increases crayfish and sculpin predation on amphipods. The presence of obvious epibenthic prey (mudsnails) may increase foraging by these predators, resulting in increased consumption of cryptic, subsurface prey (amphipods). While crayfish digest mudsnails effectively, a proportion of snails (20-50%) consumed by fish survived gut passage intact, indicating that fish derive little energetic benefit while serving as a potential transport vector for mudsnails. The effects of New Zealand mudsnails in this estuarine system include positive direct and indirect effects on crayfish, mixed direct and indirect effects on fish predators, and negative indirect effects on amphipods.

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FACILITATION OF EXOTIC SPECIES BY HABITAT- FORMING ORGANISMS AND ASSOCIATED ASSEMBLAGE EFFECTS

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Oral Presentation

Biological introductions of species to regions outside their known natural distributíon are one of the major threats to native biodiversity worldwide. In aquatic environments biogenic habitats formed by bivalve molluscs modify the original habitat, usually increasing complexity and/ or heterogeneity. This increase in secondary space may cause the abundance and/ or diversity of associated species to be greater than on substrata without these habitats. The presence of biogenic habitats and their provision of otherwise limiting resources (e.g. food and refuge from predation) may however, also facilitate colonisation, increase in abundance and aid further spread of exotíc organisms. Successful colonisation by exotíc organisms and their subsequent survival and abundance may then be dependent on the facilitatíve effects of different habitat-forming species. The North American isopod *Cirolana haifordi,* which has been introduced to many regions, including Japan, Russia and Australia, is found in bivalve biogenic habitats in Sydney Harbour. If the facilitation model is correct then I predicted that C. *haifordi* would be more abundant in places where bivalve biogenic habitats are present and that different habitat-forming species would have different effects on the abundance of the isopod. Manipulative experiments using two species of mussels and oysters (as habitat-forming organisms) anda combination of living, dead and mimic bivalve habitats showed that habitat-forming species modified the abundance of exotic isopods. Understanding the effects of different habitat-providing species on the abundance of exotic species will increase our knowledge of mechanisms explaining distributions of exotic species.

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VARIABLE DIRECT AND INDIRECT EFFECTS OF A HABITAT MODIFYING INVASIVE SPECIES ON MORTALITY OF NATIVE FAUNA

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Oral Presentation

Habitat modifying invasive species can profoundly influence predation rates of native prey, but the potentially contrasting mechanisms by which they do so have seldom been examined. *Caulerpa taxifolia* is one of the most effective invasive species of shallow water marine systems globally, often provisioning habitat de novo in areas previously lacking in vegetated structure. This structure potentially decreases prey mortality by directly reducing predator encounter rates. However, *Caulerpa* also substantially alters physical and chemical properties of the surrounding water and sediment, potentially increasing predation rates by modifying traits of resident prey. We experimentally evaluated the direct effect of *Caulerpa* to provide refuge for the native clam, *Anadara trapezia,* and how this balances with two trait-mediated indirect interactions that may increase *Anadara's* susceptibility to predators. Specifically, *Anadara,* though normally buried, in invaded areas projects from beneath the sediment, exposing itself to predators and declining in condition and predator resistance properties. Our results show that adult *Anadara* are not influenced by direct effects of *Caulerpa* on predator search and encounter rates, nor by *Caulerpa's* indirect effect of increasing predator exposure of clams via their protrusion aboveground. Rather, poor condition caused by *Caulerpa* exposure increased *Anadara* mortality. Remarkably, the higher rate of mortality on poor condition clams that are normally found in *Caulerpa* occurred despite our surveys that documented *Anadara* predators spend substantially more time in unvegetated areas. Our study helps to underscore that the specific mechanisms by which habitat modifying species influence mortality rates can arise not from the obvious direct effect of protective structure, but indirectly through modifications of traits of prey species responding to the habitat.

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INTRODUCED MARINE SPECIES IN PALAU: USING EDUCATION AND TRAINING TO ESTABLISH MARINE BIOSECURITY OUTCOMES

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Poster Presentation

To fully manage marine biosecurity issues, baseline data about the introduced species present within a country's jurisdiction is required. To this end, the Australian Maritime College representing the Marine Biosecurity Education Consortium has implemented a number of training projects on introduced marine species surveys in ports, marinas and pristine regions in a number of different countries.

In July 2007, eleven Palau organisations (govemmental, non-governmental), the IUCN, the Australian Maritime College representing the Marine Biosecurity Education Consortium implemented an introduced marine species port survey training workshop that included a very preliminary look at a number of targeted locations in the State of Koror, Palau. The survey training followed the Hewitt and Martin protocols (also known as the CRIMP protocols), using both quantitative and qualitative methods to sample soft and hard substrates. Ad hoc sampling of a number of commercial vessels and locations also occurred.

Previous biodiversity research in Palau had detect ed five probable introduced species and 1 5 possible (cryptogenic) species . Comparatively, within tropical waters ofthe Pacific (Palau, Guam, Samoa, and tropical Australia) 125 introduced and cryptogenic species have been detected . Preliminary analysis of the species detected during the survey occurred while in the field, with 11 introduced, two cryptogenic, and seve n potentially introduced species being detected. Of concern was the presence of at least one introduced species (the bryozoan *Watersipora subtorquata)* on the hull of an international recreational vessel that was not detected in the sites examined during this preliminary surve y. Also, of concern is the detection of a barnacle belonging to the genus *Chthamalus* at the soft coral arch (a major tourist destination) on mooring buoys. A species in this genus, *Chthamalus proteus,* invaded several locations in the Pacific (Guam, American Samoa, Hawaii) and has the propensity to heavily foul infrastructure and become an economic nuisance species. Five other introduced, cryptogenic and potentially introduced species were also detected at tourist destinations.

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PREDICTING THE RISK OF INTRODUCED MARINE SPECIES TO THE GALAPAGOS ISLANDS.

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Oral Presentation

The Galapagos Islands are synonymous with biology, biodiversity and natm:al selection. As isolated oceanic islands the Galapagos offer a unique opportunity to examine the invasion processes that are occurring in the region. In this year, Darwin's 200th birthday, it's even more important to understand the marine threats to this region. One of the threats that have rec ntly been analysed using risk analysis is introduced marine species. We undertook a risk analysis that comprised three risk assessments: 1) species (hazards) analysis; 2) vector analysis; and 3), pathway analysis to determine the risk of exposure that the Galapagos Islands are facing with regards to introduced marine species. The analyses started by using a 'strawman' risk framework model that we then 'road tested' on site at the Galapagos via interviews with managers (park managers, quarantine officials, Navy personnel) and scientists. These interviews established threshold limits for the appropriate level of risk and the acceptable level of consequence (impact).

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CAN AN INTRODUCED SPECIALIST PARASITIC CASTRATOR ELIMINATE ITS HOST?

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Oral Presentation

Griffen's isopod, *Orthione ariffenis* was probably introduced to North America with ballast water from Asia in the 1980s. *Orthione 9rifjenisis* the first introduced bopyrid to be recognized anywhere in the world and also is one of the first obligate marine species introduced to the eastern Pacific. Blood loss to O. *9riffenis* infestations effectively castrates the females of its new native host, the blue mud shrimp, *Upo9ebia pu9ettensis. Orthione 9riffenis* occurs in every *Upo9ebia* population examined between Morro Bay, California and Bamfield, British Columbia and since its arrival, dramatic declines or local extinctions have occurred in ali *U. pu9ettensis* populations examined. These population declines and extinctions of *Upo9ebia* and the apparent uniform occurrence of *Orthione* indicate *Upo9ebia* could be threatened by this new invader. Specialist parasites are normally expected to decline to low abundances or extinction as host populations decline and then hosts are expected to recover. These conditions however do not appear to occur with this new invader. *Orthione* locate *Upo9ebia* even at extreme low densities and persists in reservoirs of sterile old hosts, from which it continues to produce infective propagules and limit or eliminate *Upo9ebia* reproduction over multiple generations. This non-coevolved parasite thus appears capable of eliminating its new host and even itself. Density dependent mechanisms normally used in epidemiological, stock assessment and propagule-pressure models to explain coexistence between specialist parasites and coevolved hosts may not be appropriate for non-coevolved, introduced specialist parasites and native hosts.

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CURRENT STATUS OF MARINE INVASIVE SPECIES IN THE WESTPAC REGION

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Oral Presentation

In contributions to the high level objectives ofIOC/UNESCO (2008-2013) on the safeguarding the health of marine ecosystem, the Seventh Session of the IOC Sub-Commission for the Western Pacific (WESTPAC) unanimously approved one regionally rooted project on the "Coastal Marine Biodiversity and Conservation", taking into account broad interests received from its member states in the WESTPAC regían. The project reviews the current situation of marine biodiversity and current disturbance and stressors on the biodiversity. One of the stressors considered in the project is the introduction of marine organisms. In the past years, the introduction of non-indigenous species into the coastal waters in many countries poses serious environmental and economic threats. However, in the WESTPAC regían, marine introduced species issue was ignored and few studies were conducted. Under the project on the coastal marine biodiversity and conservation, the marine invasive species working group has been established. Regional status on marine invasive species was reviewed, and research priorities on marine invasive species were identified. This presentation will give an overview of current status of marine invasive species and their impacts in each country in the WESTPAC regían.

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DISTRIBUTION ANO ABUNDANCE OF NON-NATIVE SPECIES IN MAJOR MARINE CANADIAN PORTS ON BOTH THE WEST ANO EAST COASTS

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Poster Presentation

Aquatic invasive species (AIS) can have significant negative effects on native ecosystems by manipulating their functions, disrupting interactions of native species and altering the societal and economic value of these native environments. Commercial shipping activities associated with international ports (e.g., ballast water discharge, hull fouling) expose these environments to a variety of potential AIS. Thus, harbours representa critica! entry point for potential invaders with more invaders expected in ports with greater shipping activities (propagule pressure). Further, commercial ports are exposed to a number of additional anthropogenic stressors potentially making them more vulnerable to AIS establishment. During summers of 2007 and 2008, extensive intertidal surveys were conducted in 16 major international ports along the West Coast of Britísh Columbia and the East Coast of Nova Scotia to determine the composition and distribution of native and non-native species. Eight non-native species were identified in the West Coast ports. Among them, Manila clam *(Venerupis philippinarum),* varnish clam *(Nuttallia obscurata)* and soft-shell clam *(Mya arenaría)* were found to be the most abundant. These species were commonly found in the upper intertidal zone, while native bivalves were frequently associated with the low intertidal zone. On the East Coast, only four invasive species were identified. Among them, *Carcinus maenas* and *Littorina littorea* were found to be the most dominant non-native species. Relationships between abundance and distribution of AIS and ballast water exchange and ship traffic were examined to determine the relationship between AIS establishment and commercial shipping intensity. Results of these surveys may pro ve to be useful tools for risk assessments and could be used in present port management plans as well as for the prevention of future invasions .

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l'l{OPAGULE PRESSURE ANO DISTURBANCE INTERACT TO OVERCOME BIOTIC RESISTAN CE OF MARINE INVERTEBRATE COMMUNITIES

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OriJl Presentation

l'ropagule pressure is fundamental to invasion success, yet our understanding of its role in the marine domain is limited. Few studies have manipulated or controlled for propagule supply in the field, and consequently there is little empirical data to test for non-linearities or interactions with other processes. Supply of non-indigenous propagules is most likely to be elevated in urban estuaries, where vessels congrega te and bring exotic species on fouled hulls and in ballast water. These same environments are also typically subject to elevated levels of disturbance from human activities, creating the potential for propagule pressure and disturbance to interact. By applying a controlled dose of free-swimming larvae to replicate assemblages, I was able to quantify a clase-response relationship at much finer spatial and temporal scales than previously achieved in the marine environment. I experimentally crossed controlled levels of propagule pressure and disturbance in the field, and found that both were required for invasion to occur. Only recruits that had settled onto bare space survived beyond 3 months, precluding invader persistence in undisturbed communities. In disturbed communities initial survival on bare space appeared stochastic, such that a critical density was required before the probability of at least one colony surviving reached a sufficient level. Those that persisted showed 75% survival over the following 3 months, signifying a threshold past which invaders were resilient to chance mortality. Urban estuaries subject to anthropogenic disturbance are common throughout the world, and similar interactions may be integral to invasion dynamics in these ecosystems.

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TEMPORAL SCALE: MISSING AGENT IN THE INVASION PARADOX?

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Oral Presentation

Efforts to understand the link between diversity and invasibility have been challenged by conflicting lines o evidence, where the relationship seems to vary with methodology and scale. This has become known as th 'invasion paradox', and is commonly attributed to diíl'erence in the spatial cale at which srudie are conducted. Spatial scale may account for sorne of the varfarion, but not ali. The temporal cal of inva ion might al o be important, beca.use as the process of invas io n cbang from col nization to pcr istenc , tbe au al proces·es afTecting invader abundance might also chang . We pro pose a concep tual mo cle l to ex plai how thc temporal cale of invasion might affect the diver ity-inva ibility r latio nship . Thc model predicts that in tbe presence of a disturbance gradient, the diversity-invasibility relationship should be negative during the colonization phase ofinvasion (short -term), but positive in the persistence phase (long-term). We experimentally tested this model in the field usin g e. sile marin e invertebrate communities. These fauna are functionally similar to terrestrial plants, but und e rgo ucces sion ata faster rate. We found strong evidence of temporal change in the diversity -invasibi lit y relation ·hip and patterns mostly supported the proposed conceptual model. Invaders best colo niz d com mun ities under high disturban e regimcs, producing a negative diversity-invasibility relation h.ip shortly after arrival. lnvadei· persist d be t in low disturbance conditions, however, creating a positive diver ity-in\'asibilit · relation hip after *6* month . Neither of these trends appeared causal, but were likel)· mediated by dj ·turbance. We al o found evid ence to suggest intrinsic effects of diversity on invasion re i tance, althougb eITects wcre weak compared to disturbance-induced changes through time. Since experiments generally measure the colonization of invaders and surveys measure persistence, these results suggest that temporal effects may have contributed to the invasion paradox.

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RECREATIONAL BOATING: A SIGNIFICANT VECTOR OF INVASIVE SPECIES IN THE MARINE WATERS OF BRITISH COLUMBIA, CANADA

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Oral Presentation

Marinas and harbours worldwide are und r threat both from new introductions and stepping stone or econdary introduction . Recreational boating i an acknowledged vector for aquatic invasive species (AIS) but i often dwarfed in rescarch effort and pubüc perception by commercial shipping (e.g., ballast water). Onl a handful of tucües have ought to examine the role of this vector in the introduction and spread of nonindigenous species. The Canadian Boat Survey was launched in April 2008 to address the lack of information on the recreational boating vector in marine waters. lt is composed of two research components: a boater questionnaire and underwater hull inspections. The questionnaire is aimed at all boaters utiüzing British Columbia waters but will be expanded to include other regions in Canada. The questionnaire gathers data on boats, antifouling practices, and regional and international boat movements. Re ponse rat is enhanc d through outreach a<.:tivitie · and the development of a website. Concurrently, hull in pections were unde.rtaken to categorize th hu11 fouling community (composition and abundance). Boats **at** 14 marinas throughout Briti h Columbia , cr photographed using SCUBA and examined for the presence of nonindigenous species. A high percentage of boats examined (30.6%) had at least one nonindigenous species attached or entangled. While only three percent of boats surveyed originated from US waters, 17% had traveled to the US in the past 12 months. There was an substantial difference in hull fouling levels between transient and resident boats. As a consequence, transient and international boats will be the focus of dive surveys during the 2009 field season. Linking the hull photographs to the boater questionnaire results feeds into the creation of a spatial model of regional spread. The results of this work will allow scientists and managers to target risky boating behaviours and prioritize areas for monitoring.

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RESOLVING NATURAL RANGES AND MARINE INVASIONS IN A GLOBALLY DISTRIBUTED OCTOCORAL (GENUS CARIJOA)

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Oral Presentation

The first published report of the invasive snowflake coral in Hawaii comes from Pearl Harbor in 1972. Subsequent identification of this species as the octocoral Carijoa riisei led to the general conclusion that it arrived via maritime vectors from the Caribbean. In an attempt to confirm the source of the Hawaiian population, we used rnitochondrial (h = 0.8379; π = 0.0022) and nuclear (H = 0.8904; π = 0.0299) data to compare Hawaiian specimens with Carijoa samples collected worldwide (n=248). In addition, vessel traffic patterns for the Pacific Ocean were examined for 1940-1979 to determine maritime connectivity to and from Hawaii during the assumed time of introduction. Combined mitochondrial and nuclear data show both higher and considerable unique genetic diversity in the Indo-Pacific compared to samples from throughout the Caribbean-Atlantic, suggesting that the species is native to the Indo-Pacific. Further, C. riisei sampled from throughout Hawaii (n=96) share none of the Caribbean mtDNA haplotypes (29 unique haplotypes) and only a single nDNA allele (of 29 unique alleles), indicating that the Hawaiian populations derive from Indo-Pacific rather than Caribbean-Atlantic origins. Despite an active commercial vessel route between Hawaii and the Panama Canal, we find no evidence to support a maritime introduction of Carijoa riisei from the Caribbean-Atlantic. Furthermore, isolation-by-distance (IBD) analysis indicates a significant correlation between genetic and geographic distance in the Indo-Pacific and Hawaii, but not for the Atlantic contrary to ali published literature.

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RELATIVE CONTRIBUTIONS OF DOMESTIC ANO FOREIGN SOURCED BALLAST WATER TO PROPAGULE PRESSURE IN PUGET SOUND, WASHINGTON, USA

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Oral Presentation

The global movement of aquatic organisms in ship ballast water is a known pathway for the introduction of non-indigenous species (NIS) to coastal ports. One key to successful NIS establishment in coastal waters is propagule pressure - the size and frequency ofNIS inoculations. We estimated propagule pressure of coastal zooplankton delivered in ballast water to Puget Sound, Washington, USA, which receives 7.5 x 106 m3 of ballast water annually. We weighed the relative propagule pressure from domestic and foreign ballast water, in terms of propagule size (number of individuals), frequency of NIS occurrences, and diversity (number ofknown NIS species). Ship discharge volume was nota good predictor of coastal propagule pressure. Instead route type (domestic or foreign) and ballast water exchange status (exchanged in mid-ocean vs. unexchanged) were much better predictors of propagule supply. Overall, while the diversity of known non-indigenous zooplankton was higher in trans-oceanic ballast, the annual discharge of coastal zooplankton propagules to Puget Sound was much greater for ships conducting domestic voyages. These results suggest that intra-coastal ballast water must be further scrutinized as a vector for NIS introduction, and calls into question regional "common-waters" agreements that allow vessels to move ballast without conducting ballast water treatment.

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TEMPORAL DYNAMICS OF INVASIONS AND THE LAG EFFECT

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Oral Presentation

One of the fundamental goals of invasion biology is to better understand the temporal nature of invasions - to answer the question of "when?" In sorne instances, the initial invasion event appears to representan ecological release, where the invader, having left behind natural enernies, rapidly comes to domínate new territory. However, in many cases an ecological explosion appears to come only after the burning of a long fose. These temporal lags are often associated with population-level dynamics such as increases in the number of invaders or their geographic range, but lags occur throughout all aspects of invasions, including human responses to them. Although lags provide an opportunity to examine basic ecological and evolutionary dynarnics, a primary interest in lags relates to their tendency to cause "ecological surprises." An important principle regarding lags is that they, in and of themselves, do not necessarily decrease predictive ability. Sorne lags are inherent and expected, but a startling array of unexpected lags have also been documented anda variety of evidence suggests that invasion dynamics can take decades, centuries, or even millennia to play out. Given that scientific activities and management actions typically take place over far more compressed timescales, it is necessary to incorporate longer-term perspectives to effectively understand and manage invasions.

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PATHWAY TO INVASION: FROM ARTIFICIAL STRUCTURE TO ROCKY REEF

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Oral Presentation

Artificial structures differ from natural rocky reefs dueto their physical characteristics. Most jetties and pontoons present large areas of vertical substrata and are relatively shaded, which reduces competition from many algal species aríd allows the development of assemblages dominated by sessile invertebrates. They are also regularly disturbed by cleaning and maintenance and this may play a role in providing a foothold for arriving invaders. In contrast, natural habitats are thought to provide barriers to invasion through the biotic resistance of native residents. We compared hard-substrate assemblages on pilings, pontoons and rocky reef in Sydney Harbour. We found greater non-indigenous diversity and dominance on piers and pilings relative to rocky reef. However, sorne non-indigenous invertebrates and algae were present on the reef. We tested the hypothesis that the ability to invade natural rocky reef is influenced by shading, orientation and biotic resistance. Experiments were deployed simultaneously at two rocky reef areas in Sydney Harbour. Sandstone plates were subjected to shading treatments and were positioned vertically or horizontally. Half the plates were bare at deployment and halfhad 1-year old assemblages present (65-90% cover of *Sar9assum* sp.). The plates were deployed for seven months and then algal canopy was removed and weighed, and the remaining assemblage censused live. Exotic species were better able to invade vertical substrate and were advantaged by the availability of bare space. These fmdings suggest that management efforts should be targeting reefs where vertical walls are prevalent and areas exposed to high levels of physical disturbance.

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ANALYSIS OF VESSEL PATTERNS TO IMPROVE A BIOFOULING RISK ASSESSMENT MODEL

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Poster Presentation

Management of nonindigenous aquatic species (NAS) associated with biofouling is difficult given limited information and resources. Risk assessment aids this management by clearly defining the components of the decision involved, taking into account potential impacts on environmental, economic, social, and cultural values, as well as identifying where additional research is needed. The biofouling risk assessment model used in this assessment consists of two parts: the probability (likelihood) and magnitude of impacts (consequences) ofNAS introduction, both ofwhich are subject to high degrees ofuncertainty. This project "'·ill focus on one component of the likelihood analysis, vessel transport patterns. Factors such as where vessels come from, where they go, how long they take to get from port to port, and their duration in port, all effect the likelihood ofuptake, transport, survival, and introduction ofNAS. For example, 'days spent ir port' *far* a vessel is an important factor for both uptake in port of origin and inoculation in port of destination, as a long period in port can provide a species with enough time to become established on a vessel or on a port substrate. However, many of these vessel patterns are unknown. Here, vessel transport patterns to Australia from 2002-2007 are analyzed to improve understanding and reduce uncertainty withir the risk assessment process. The analysis will present the relationships between days in port, vessel category, bioregion(s) visited, and vessel speed. Where data is available, these analyses have been combinec with NAS presence/ absence data within bioregions to provide additional support to the risk assessment model.

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INTEGRATING GENETIC AND VECTOR ANALYSIS TO ASSESS INVASION PATHWAYS OF THE CLUBBED TUNICATE STYELA CLAVA IN THE NORTHEASTERN PACIFIC

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Oral Presentation

Recognizing the pattems by which established invasive populations expand their ranges is crucial to understanding the risks posed by those species. Here we integrate two methods commonly adopted to assess likely pathways of invasive spread: genetic inference of connectivity between established populations and analysis of anthropogenic vector movements between potential recipient regions . We employ these methods to reconstruct the expansion of the clubbed tunicate *Styela clava* in the northeastern Pacific. *Styela clava* has become a common component of fouling communities from Northem Mexico to British Columbia, and has provena costly nuisance species where found in high densities. Mitochondrial cytochrome c oxidase subunit I (COI) sequences and multilocus genotype data from 12 polymorphic nuclear microsatellite loci were generated for a total of 433 individual tunicates from thirteen populati ons. Descriptive statistics indicate that levels of genetic diversity range broadly, with sorne populations showing signatures of strong founder effects . Significant genetic structure is observed across the introduced range, with particularly strong differentiation observed between samples in southern California and those in Puget Sound/Georgia Strait . We utilized data on the strength of commercial ship traffic between ports in our study area to test the hypothesis that movement of these vessels explains the observed genetic structure. Results of these analyses indicate that connectivity between samples vía commercial shipping is a poor predictor of genetic structure, suggesting that alternative hypotheses must be explored. In particular, our data raise the possibility of multiple independent introductions to the Pacific coast of North Amer ica.

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ſ\ Hl · Vll ·. W < >l: Sl 111' i:OULING AS A VECTOR OF MARINE ORGANISMS ANDAN INVISl'l<;ATION OF VOYAGE IMPACTS ON THE INVASION POTENTIAL OF SHIP FOULING COMMUNITIES

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Oral Presentation

In the past decade, there has been a substantial increase in analyses of biological invasions associated with the fouling communities of ships. This research effort has focused primarily on characterizing species richness and (to a lesser degree) the extent of fouling on ships' submerged surfaces. There has also been a parallel indirect approach, assessing the extent to which existing invasions may have resulted from hull-mediated transfers, based upon information about habitat utilization and üfe-history characteristics of nonindigenous species (NIS). Together, these analyses have provided considerable insight on: 1) the taxonomic patterns of organisms found on vessel hulls; 2) the prevalence of NIS on hulls; and 3) the overall and relative contribution of the fouling vector to the initial establishment of NIS. In a review ofliterature, we counted 1128 species from 21 phyla or divisions that have been recorded on ships' hulls. Ship fouling was implicated as a vector in 73% of 553 different established NIS among 8 temperate locations in Europe, North America and the Antipodes. The vector process (effect oftransit) is poorly understood, however, because only 9vessel voyages from 5 studies have documented fouling diversity and abundance at source and destination ports. These limited data indicate a variety of responses to environmental conditions of voyages, rangingfrom complete removal ofbiota to unexpected increases in species richness. Experimental approaches to evaluating post-voyage organism condition are also largely absent from the Üterature. As a starting point, we have tested the impact of osmotic stress on fouling communities, mimicking Panama Canal transits by ships, and found non-lethal (resistance), sub-lethal (apparent resilience) and lethal impacts on different components of assemblages after freshwater immersion. We also recorded reproductive activity (spawning and egg release) by stressed fouling species. Further experimental and detailed observational approaches to biofouling vectors are requir ed to better understand existing NIS patterns and for forecasting future incursion threats from ships' submerged surfaces.

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ACCELERATED EROSION OF SALTMARSHES INFESTED BY A NON-NATIVE BURROWING CRUSTACEAN

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Oral Presentation

Non-native ecosystem engineers can have profound impacts to native communities by modifying the physical structure of marine habitats. In many estuaries of the Pacific coast ofNorth America, the non-native Australasian isopod *(Sphaeroma quoianum)* creates dense burrow networks in marsh banks and other substrata. Dense aggregations of isopods and burrows weaken the marsh and may accelerate erosion. Our research seeks to quantify the erosive impact of burrows between infested and uninfested saltmarshes and between paired burrowed and unburrowed areas within infested marshes (thus controlling many other factors affecting erosion). In each marsh, we measured the lateral erosion rate (through erosion pins and onshore reference markers), amount of undercutting, and the number ofbroken marsh sections over one year. All measures of erosion including lateral erosion rate, the amount of undercutting, and number of broken marsh sections, were greater in infested marshes than uninfested marshes. When coritrolling for the spatial differences between marshes, a similar pattern emerges. Within infested marshes, lateral erosion was three times greater in burrowed areas than adjacent unburrowed areas. Thus, the burrowing impact of *S. quoianum* appears to accelerate the erosion of marshes, which may have cascading impacts to the myriad species dependent on saltmarsh ecosystems.

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TI **11:** IMPACT OF A NATIVE FISH SPECIES, TAUTOGOLABRUS ADSPERSUS (CLINNLR) ON LOCAL ANO INVASIVE TUNICATES IN THE GULF OF MAINE

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l'ostcr Presentation

As a major marine predator, *Tauto9olabrus adspersus* (Cunner) has a significant impact on the benthic invertebrate community colonizing a new substrate. Marine coastal construction such as piers and wharves creates new habitats; the community of species which develop in association with these new habitats experience predator prey dynamics between newly settled benthic organisms and newly recruited predatory species. Often, the substrate of such habitats is colonized by opportunistic species among which are local and invasive tunicates. The aim of this study is to assess the impact of Cunner on the benthic community colonizing a new substrate with emphasis on local and invasive tunicate species. Benthic organisms were allowed to colonize panels established at the Coast Guard Pier in Portsmouth NH and Wentworth Marina in New Castle NH from May until Novem ber . Panels are 10cm2 plexi-glass and are designed to function as a new substrate for the colonization ofbenthic organisms. Three treatrnent methods were designed· a eries of panel expo d only to unner predation, a series ofpanels allow ed access of n h, . ea tar, ancl lobster populations and a ser ie of' panels enclosed in cages, blocking access of all predators to the panel. O ver the course oí the e xp riment, changes in percent cover of invertebrate species on each pan I were utili ed in order to assess the impact of Cunner as a predator on the community thr ougho ut the 6eld e on. In addition, vaiiations in percent cover between treatrnent types were calculat ed in orde r to a th impact of Cunner. Fu1·thermore, aquarium feeding trials were designed in order to both corroborate with any field findings and assess in situ feeding behavior of Cunner. I anticípate that Cunner will have a significant impact on the community assembl ges growing on the panels. In particular, I expect that Cunner will have a significant impactas a predator upon tunicate species such as *llol9ula* pp. and the inv a ive *Ciona incestm alis.* Th value oí this tudy lies in the increasing understanding of thc impa t of a native pedes on both lo al benthi organi m and introduced invasive benthic organisms. Examining the predator pr, · dynamics ben een nati, ·e and in\'a iv pecies can lead to a greater under tanding of the impact oí intr duced ·p cies to I cal community ecology. In future work, I plan to examine the search image cues used by Cunner to locate tunicate prey. As this fish is successful in foraging for both native and invasive sp ecies, it is of particular interest to discover what foraging skills allow the Cunn er to capitalize on the introduction of a new food source.

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GREEN CRAB CONTROL: A REMOVAL EFFORT IN A SHALLOW CENTRAL CALIFORNIA ESTUAR Y

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Crab Control Workshop Presentation

Biological invasions continue to pose a considerable threat to native ecosystems worldwide, including marine and estuarine habitats. Therefare, it is important to identify effective approaches and tools for managing the many established populations of non-native marine species as well as newly invading ones. Following terrestrial successes at controlling large, connected populations, we set out to explore the feasibility and effects of locally removing a well-established population of a marine organism with pelagic larvae, the European green crab, *Carcinus maenas.* This project represents a conceptual shift in the development of management options to address established invasions in marine systems. Our specific goals were to evaluate the overall control effort as well as to identify best management practices by comparing the effectiveness of different sampling techniques as we removed adult European green crabs, *Carcinus maenas,* from Bodega Harbar, California. C. *maenas,* which was first detected in Bodega Harbar in 1993, is a voracious predator that impacts mariculture species and the composition of the soft-sediment community. Based on our removal efforts in Bodega Harbar since July 2006, we evaluate methods, timing, and effort of removal and different marking, abundance and population measures far these crabs. We also assess the effectiveness of our management measures, through comparing standardized catch of C. *maenas* in Bodega Harbar to reference bays, befare and ·mul tiple times after the start of removal, following a before-after-control-impact (BACI) design. Finally, we compare our efforts to eradication and control efforts in other systems and discuss the value of local control of an established, wide spread introduced marine species.

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INITIAL REBOUND OF A NATIVE PREY SPECIES FOLLOWING MANAGEMENT OF AN INVASIVE CRAB

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Oral Presentation

Alterations to community composition, habitat structure, or ecosystem function can take years to recover or even representan alternate stable state. The rate at which (and even whether) impacted populations, communities, and their habitats rebound after removal of an established marine species has rarely been explored . As a first step in examining community changes following the management of a non-native species, we are tracking the recovery of a native crab population following intense, local removal of the non-native European green crab, *Carcinus maenas.* Among other changes to Bodega Harbor's soft sediment community tbat occurred immediately after colonization by C. *maenas,* the population of the native shore crab, *Hemi9rapsus oregonensis,* experienced a huge decline in its abundance and also exhibited a substantial decrease in average crab size. In 2006, 14 years after the invasion, we initiated a removal effort of C. *maenas* from Bodega Harbar. We also monitored predation rates on tethered *H . ore9onensis* and the numbers and size of *H. ore9onensis* numbers in traps. The survivorship of tethered *H. ore9onensis* changed significantiy across sites and with C. *maenas* removal. Initially we found that survivorship of tethered *H. ore9onensis* decreased with increasing abundance of C. *maenas.* Once we decreased C. *maenas* abundance, this relationship vvas no longer strong. Fewer tethered *H. oregonensis* were consumed in sites where many C. *maenas* were removed. Catch and average size of the native crab also increased. One year after we began removal, our catch of *H. ore9onensis* in our four core removal sites had increased four fold. Recruitment for all crabs in Bodega Harbar (and elsewhere) was poor in 2008. The average body size of *H. ore9onensis* increased by about 15% from 2006 to 2007. Our results suggest that C. *maenas* removal has resulted in a rapid increase in size and abundance of the native crabs due to reduced predation pressure. We prediet rapid and sustained rebound for this and other key prey species in estuaries once intense predation from this non-native species has been alleviated. More broadly, this may be a general and expected outcome from removal of such keystone predators.

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LINKING PHYSIOLOGY, BIOGEOGRAPHY AND SUCCESS OF NON-NATIVES IN SUBTIDAL COMMUNITIES IN THE GULF OF MAINE

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Poster Presentation

Physiology has been used to establish the biogeographic distribution ofmultiple ectothermic species (e.g., mussel, tunicate, crab). However, the connection between predicted distribution of species, their dominance and impacts on local communities is not well understood. Here, we link the physiology of non-native Botryllid ascidians to temperature, growth, and biodiversity using a combination of field and laboratory experiments. Adult colonies of each *B. scblosseri* and *B. violaceus* were exposed to abrupt temperature fluctuations (4 ºC, 10 ºC, 15 ºC, and 20 ºC) in the laboratory. Heart rates, physiological system that reflects stress in marine invertebrates, were used to assess the condition of individual colonies and monitored approximately every other day for two weeks. Growth rates of species were also calculated over this same period. Spatial dominance of colonial ascidians and diversity in the field were documented using 100cm2 Plexiglas panels deployed in June 2006 and photographed after three months at four sites in the Gulf of Maine (Salem, MA, Portsmouth Harbor, NH, Damariscotta Estuary, MA and Eastport, ME). The location of each of the four sites represents a gradation in temperature. In the coastal Gulf of Maine sites, temperature ranges from -1 ºC to 25 ºC. Results revealed that heart rates and growth rates of both *B. scblosseri* and *B. violaceus* increased with rising temperatures. However, *B. scblosseri* experienced greater growth than *B. violaceus* at lower temperatures while *B. violaceus* experienced greater growth at higher temperatures. Understanding the mechanistic basis of regional biogeography and biodiversity patterns is critica! to predict the potential effects of global warming on ecosystem function.

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TROPHIC LEVEL RESPONSE OF INVASIVE SPECIES IN A SUBTIDAL SYSTEM

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Oral Presentation

lntroduced species representa serious threat to ecosystems. Many terrestrial and intertidal studies have found invasive species disrupt food webs. However, in comparison to these systems, trophic level consequences of introduced species in subtidal systems are notas well understood. Using a combination of laboratory and field studies, we examined trophic interactions between native predator/prey populations and invasive prey. We presenta conceptual model that describes the relationship between invasive colonial ascidians, a native predator, *Henricia san9uinolenta* (blood star) and its native prey species, sponges. Laboratory experiments and field surveys were used to determ ine prey choice of *H. san9uinolenta* among invasive colonial ascidians *(Diplosoma listerianum, Botryllus schlosseri, Botrylloides violaceus* and *Didemnum vexillum).* Long-term changes in the abundance of *H. san9uinolenta* populations were established through field surveys while changes in sponge populations were determined through a study comparing succession in a marine fouling community between 1979 to 1982 and 2003 to 2006. Photographs taken from several areas in the Gulf of Main e were analyzed to assess frequency of overgrowth of sponges by colonial ascidians and of overgrowth of colonial ascidians by sponges. Finally, we conducted laboratory studies to assess growth of *H. san9uinolenta* when fed only sponges or colonial ascidians. Our findings suggest invasive colonial ascidians, specifically D. *listerianum,* exert both a vertical anda horizontal control on subtidal food webs.

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INTRODUCTION AND TRANSLOCATION OF HARMFUL AQUATIC MICROBES IN THE GREAT LAKES: PATHWAY ANALYSIS

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Oral Presentation

Microorganisms are an under-appreciated threat to aquatic systems, especially in the con.te xt of invasive species. Their size generally precludes their easy notice, andas postulated by Wyatt & Carlton (2002) in their "smalls rule," the more diminutive the taxon, the less likely it is to be recognized as introduced and more likely to be considered indigenous. While the "smalls rule" applies in general, it <loes not in cases where microorganisms cause an easily observed or economically important biological effect, e.g., the large-scale, previously unknown mortality of Great Lakes fish infected with viral hemorrhagic septicemia virus, almost certainly an introduced pathogen.

There are other cases in the Great Lakes where microorganisms exert deleterious effects, but the causative species are not necessarily non-indigenous. Examples of such microorganisms include the agents of avían botulism and harmful algal blooms, especially toxin-producing cyanobacteria.

Yet another category of microorganisms includes those that are clearly non-indigenous, but for which it is unclear whether they are harmful or could be in the future. Throughout Lake Erie, for example, Wilhelm et al. (2006) found viruses (cyanophages) that infecta marine cyanobacterium. The viruses are clearly related to marine cyanophages, but their pervasive distribution in the Lake leaves open the question about their host.

Vector analysis is a tool that can help policy-makers and water-quality managers evaluate options to interdict the introduction of non-indigenous species orto contain those already delivered (Ruiz & Carlton, 2003). Here we develop such an analysis for the introduction and translocation ofharmful aquatic microbes. We take as a starting point the more general scheme of Lodge et al. (2006) and focus on microbial threats to the Great Lakes.

The microbial groups we considerare harmful microalgae, pathogens of humans, and pathogens of aquatic animals. In addition to specifying vectors whereby microbes may enter and disseminate throughout the Great Lakes, we also rank their probability of expression. We show that likelihood estimates Yary according to the particular microorganisms under consideration, but overall, recreational boating and commerce in animals emerge as vectors of greatest concern.

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¡;¡{(>M PAPER TO PRACTICE: LAUNCHING THE WORLD'S MOST STRINGENT BALLAST WATER STANDARDS

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Oral Presentation

In an effort to curb species invasions, California's Marine Invasive Species Program (MISP) has recently established performance standards for the discharge ofballast water. The performance standards set limits for organism concentration as a function of organism size class, and will be im plemented on a graduated time schedule beginning January 1, 201O, with a final standard of zero detectable living organisms in ballast water discharge by 2020.

A critica! step for implementation has been the evaluation of treatment technologies to determine if any will available to meet the standards within the required timeframe. In its Dec ember 2007 report to the legislature, the MISP determined that no single technology was yet able to meet California's performance standards. Of the 28 tr eatm ent systems reviewed, 20 had reportable results from performance verification testing, but only 11 systems had results based upon tests conducted onboard vessels. A major obstacle to this review was the lack of standardized methods used to verify system performance.

The MISP thus developed a standardized set of testing guidelines for use by technology developers as they · assess system compliance with California's ballast water standards and water quality objectives. These guidelines merge the U.S. Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) program generic protocols for verification ofballast water treatm ent technologies with specific methods for assessing compliance with California's standards.

An update of the 2007 assessment was completed in January 2009 and shows a significant improvement in the quantity and quality of the available data on treatment system performance. Currently, at least two treatm ent systems appear capable of meeting California's performance standards, and severa! more are expected to be available in the near future. The result s of this latest report will be discussed, as well as MISP efforts to develop protocols to verify vessel compliance with the standards.

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EFFECTS OF CODIUM FRAGILE SSP. TOMENTOSOIDES ON EELGRASS IN THE MAGDALEN ISLANDS, EASTERN CANADA

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Poster Presentation.

The green alga *CodiumJraaile* ssp. *tomentosoides* (hereafter *Codium)* is widely known to invade rocky habitats in temperate regions throughout the world. However, this species has also been reported to infest soft bottom habitat by settling and growing on eelgrass *(Zostera* marina) rhizomes. In the Magdalen Islands, southern Gulf of St. Lawrence, eastern Canada, great densities of *Codium* have been present in eelgrass beds since at least 2003. Since recent studies have shown that algal canopies can alter seagrass growth in other systems, the persistence and expansion of this invasion has raised special concerns for the eelgrass in eastern Canada.

The objective of this study was to assess in situ if *Codium* canopies have detrimental effects on eelgrass. We hypothesize that eelgrass density is negatively correlated with *Codium* cover dueto shading by *Codium* lowering eelgrass growth.

From June to October 2008, *Codium* density was manipulated in situ in an area of continuous eelgrass cover with little *Codium.* This condition was essential to associate the observed results to the treatment effects and not to a priori conditions. Single *Codium* thalli were attached to 30 cm aluminium rods and randomly distributed within circular plots (1. 3m diameter) to create the following treatments: 1) high *Codium* density (60 thalli), 2) intermediate *Codium* density (30 thalli), 3) low *Codium* density (15 thalli), 4) control forno canopy and 5) control for manipulations (60 aluminium rods without thalli). Plots were separated by at least 10m and each treatment was replicated five times. The plots were visited periodically to remove extraneous drift *Codium* fragments and to maintain the *Codium* density.

Eelgrass density was significantly reduced dueto *Codium* but only under the highest *Codium* density treatment two months after the beginning of the experiment, decreasing from 808 ± 64 shoot m-2 in June to 407 ± 55 shoot m-2 in August. *Codium* density had no effect on above- and below-ground eelgrass biomass as assessed at the beginning Qune) and the end (October) ofthe experiment. These results suggest that the effect of *Codium* on eelgrass depends on algal canopy density and can occur over a single growing season.

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RE-EVALUATING ERADICATION OF NUISANCE SPECIES: INVASION OF THE TUNICATE, CIONA INTESTINALIS

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Oral Presentation

Eradication is an important concept in the management of biological invasions, but it is rarely consideredin practice. This may be because managers commonly work with incomplete data and little orno practica! guidance. Past eradication frameworks provide sorne useful criteria, but do not provide quantitative guidelines. Here, we argue that eradication is not always adequately considered, and we develop a framework for rapid assessment of its feasibility, despite limited data. This quantitative model offers criteria to rapidly assess the potential for eradication and provide estimates of the necessary effort and timing, and of the size of the target area. This framework is applied to a recent tunicate (Ciona intestinalis) invasion around Prince Edward Island, Canada, which is causing considerable economic damage to harvesters ofblue mussels (Mytilus edulis). Our framework suggests that eradication may be feasible and, based on a cost-benefit analysis, could require only a >16% chance of success to constitute a worthwhile risk.

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INTRODUCED AND CRYPTOGENIC MARINE BIOINVASIONS OF THE HAWAIIAN ARCHIPELAGO

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Oral Presentation

We examined the historical biogeography of nearly 500 species of marine and estuarine protists, fungi, invertebrates, fish, algae, and flowering plants in the Hawaiian Archipelago, ranging over 1O degrees of latitude from the island of Hawaii to Kure and Midway Atolls. W e resolved 301 introduced and 117 cryptogenic species, along with 72 species of unknown establishment, failures, natural waifs, erroneous records, and other dispositions. Habitats covered include the supralittoral, the intertidal and sublittoral, including the non-native parasites, commensals, and other symbionts in these communities. Fifty-three percent of non-native biota are crustaceans, insects, mollusks, and ascidians; bryozoans, polychaetes, cnidarians, pycnogonids, fish, algae, and flowering plants account for an additional 38%. Eight-five percent of invasions are associated either with ship-related vectors (70%) or with intentional releases (and associated accidental transport of epibiotic/ endobiotic species) by private individuals or govemment agencies (15%). Ballast water accounts unequivocally for only 10 invasions (3%), because ballast water cannot be distinguished from other vectors (largely ship fouling) for 92 species, or nearly one-third (30.6%) of the introduced biota. Ship fouling as the sole vector accounts for approximately one-third of Hawaiian marine invasions. lntentional releases fall into two broad periods: 1895 to 1939, when 10 species were imported over a 45 year period, and 1950 to 1974, when 17 species were imported over a 25 year period. While intentional releases constitute only 9% of the non-native biota, many of these fish, algae, and higher plants are now abundant, aspect-dominant species. Nearly half (45 .5%) of all invasions derive from the lndo-West Pacifi.c (IWP); the next largest fraction arises from the warm Atlantic Ocean (AO; 21.6%), while only 7.2% derive from the Eastern Pacific and 2.3% from the Nearctic-Palearctic. Seventy species (23.3%) of unknown origin may derive largely from the IWP or the AO. Temporal pattems are difficult to resolve, dueto thelack of historical collections in the 18th, 19th, and early 20th centuries: while only 11 introduced species had been collected before 1900, many species first collected in the 20th century-may have arrived many decades earlier. Finally, we address the scale of ecological and environmental impacts that this rich exotic biota has had on the most isolated archipelago in the world.

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ENVIRONMENTAL TOLERANCES ANO PREDATION SUSCEPTIBILITY OF INVASIVE ASCIDIANS IN BRITISH COLUMBIA, CANADA

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Oral Presentation

Four invasive ascidian species *(St)'ela clava, Botryllus schlosseri, Botrylloides i,iolaceus,* and *Didemnum vexillum)* have been identified at many locations in British Columbia (BC), but these species have not proliferated to the same extent they have in Atlantic Canada, where recent ascidian invasions have resulted in significant challenges for the aquaculture industry. We conducted a series oflaboratory experiments to assess environmental tolerances and potential predation effects on survival and growth of these asicidians in order to assess the potential far abiotic and biotic interference to limit the establishment and / or spread of these species in BC . Botryllids exhibited broad temperature and salinity tolerances (5-25 °C , 14-38%0), suggesting that they might be able to exist in, or invade to, most coastal ar eas of BC provided that other criteria for their survival and growth are met. A number ofbenthic inve rt ebrate species (sea urchins, sea ·tars , nudi bra nchs, and crabs) we re found to pr,e o n in vasiv e ascidians. Although predation alone is un likel y to preve nt large - cale stabli hm ent and pread of non -indig enous ascidians in BC, it may have the poten tial to ig nifican tl reduce lo calized populations and their impacts. Green sea urchins were found to be the mo t effi· ent predators, consum ing 12. 7 ± 5. 14 cm2 of adult *B. violaceus* o ver a 3-day period and **63. 5± 28 .80 juvenile co l nic oí *B.*** *schlcsseri* overa 2-day period . Currently, we are evaluating the efficiency and practicality of mechanical, chemical, and biological control methods for invasive asicidians in both shellfish aquaculture and marina settings . Further, we will evaluate the effects of invasive ascidian fouling and various control methods on cultured bivalves.

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PREDICTING THE NORTHWARD RANGE EXPANSION OF NON-INDIGENOUS EUROPEAN GREEN CRAB (CARCINUS MAENAS) ALONG THE WEST COAST OF NORTH AMERICA

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Oral Presentation

European green crab (Carcinus *maenas),* were unintentionally introduced from the east coast of the United States to San Francisco Bay, ca. 1989. Green crab are native to the northeastern Atlantic, but are considered invasive anda great ecological threat to the marine and estuarine ecosystems of the United States. Green crabs have been documented in nearly every major estuary along the west coast of the lower 48 andas far north as the southwest coast of Vancouver Island, British Colum bia. There is great concern that green crab populations will continue expanding northward along coastal British Columbia and southeast Alaska . Green crab expand their range to new estuaries and embayments via larval transport, and it is commonly held that this transport mechanism is vastly accelerated northward during El Niño years. We coupled National Oceanic al).d Atmospheric Administration (NOAA) Regional Ocean Modeling System (ROMS) output with larval green crab life history parameters to create an individual based model (IBM) that predicted where larvae could be transported along the west coast of North America. Larvae were released from 13 sites ranging from San Francisco Bay, California up to Riou Bay, Alaska, at various times of the year from 1994 - 2004 . We found that year ofrelease had the most profound affect on northward larval dispersa! patterns and that the warmer temperatur es associated with El Niño years did not offset the effect of decr eased time for larval settlement. It appears that San Francisco Bay is an unlikely source for current populations of green crab found on Vancouver Island in British Columbia. Finally, the model predicted that currently un-colonized areas along the coast of British Columbia and Southeast Alaska could be susceptibl e to invasion in the future .

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ECONOMIC, ENVIRONMENTAL ANO BINATIONAL CONSIDERATIONS IN CONTROLLING INVASIVE SPECIES ON HULLS OF RECREATIONAL BOATS IN SALTWATER

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Oral Presentation

Regulatory action to protect California's coastal water quality from degradation by copper from antifouling paints on recreational boats interacts with efforts to prevent transport of invasive, hull-fouling species. A Total Maximum Daily Load (TMDL) program is in place for a major yacht basin in northern San Diego Bay. Agencies have found dissolved copper levels that exceed water quality standards in boating facilities in the remainder of San Diego Bay, in Newport Bay and Marina Del Rey. The California Department of Pesticide Regulation and U.S. EPA are reevaluating antifouling paints (regulated pesticides). Extensive coastal boat _traffic in California and Baja California increases marine invasive species transport risks. Recreationists, boating businesses and policy makers need access to information on costs of effective hull-fouling control measures to address both issues. To that end various factors were investigated that iníluence the recreational boating industry in regards to fouling control options. Research included an empirical survey of 30% of the marina, boatyard and hull-cleaning businesses along the coasts, bays and Sacramento-San Joaquin Delta of California and in the Ensenada, La Paz and Cabo San Lucas areas of Baja California and Baja California Sur. The scope of data collection enabled binational comparisons. Through statistical analyses of the survey data involving summary statistical information as well as regressions, particular relationships were measured between the fouling control options and factors such as costs, frequency of boat use, length of stay at marinas, location, awareness of non-toxic coatings et alia. For example, although the range of length of stay in a marina is large, approximately half oflong term marina tenants do not take their boats out frequently. These factors present specific issues related to toxic coatings (copper and zinc based) versus nontoxic coatings (epoxy and slick) and to other fouling control measures. Regressions indicate that boats rarely leaving the marina (with a longer length of stay at the marina) and awareness of nontoxic boat bottom coatings decrease usage of copper. The data show that awareness of nontoxic boat bottom coatings is higher than it was one or two years ago. This signals a positive impact of the University of California Cooperative Extension outreach educating boaters about nontoxic coating options.

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LARVAL COMPETENCY PERIOD ANO NATURAL DISPERSAL POTENTIAL OF THE INVASIVE COLONIAL ASCIDIAN DIDEMNUM VEXILLUM

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Oral Presentation

In New Zealand, biofouling pests have resulted in adverse effects on aquaculture and environmental values andas such there is increased interest in their management. One such pest species, the colonial ascidian *Didemnum vexillum,* poses a considerable threat to the New Zealand aquaculture industry. lnitial attempts to manage *Didemnum* in the Marlborough Sounds mussel farming region failed to eradicate the species, but there is still considerable interest in whether and to what extent its human-mediated spread can be managed ata regional scale. Decisions around managing the human pathways of *Didemnum* spread must consider, among other things, the natural dispersa! potential of the species; vector management is probably not worthwhile for pathways where natural dispersa! also occurs. Here we use a weight-of-evidence approach to evaluate the natural dispersa! potential of *Didemnum.* We describe the results of a regional-scale *Didemnum* spread monitoring programme, estimate dispersa! distance from the recorded distribution of the species, and measure the distance of larval recruitment from established populations in a field experiment . These estimates are supported by an assessment of the planktonic larval competency period and description of larval behaviour in a laboratory-reared population of this species. Results showed that *Didemnum* larvae can survive up to 24 hours in the plankton while retaining the ability to metamorphose and settle successfully. Collectively, our findings indicate that *Didemnum* has the ability to spread further by natural dispersa! than assumed for most colonial ascidian species; probably hundreds of meters to kilometers depending on hydrological conditions. This information will assist managers in the implementation of effective eradication and control efforts, as understanding the importance of natural dispersal relative to human mediated dispersal is critical to the management of marine pests.

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REPRODUCTIVE SEASONALITY OF THE INVASIVE ASCIDIAN DIDEMNUM VEXILLUM: MANAGEMENT OPTIONS FOR MITIGATING IMPACTS ON THE NEW ZEALAND GREENSHELLTM MUSSEL INDUSTRY

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Poster Presentation

The introduction of a number of high profile invasive fouling species to commercially important aquaculture regions globally poses a significant practica! and econornic barrier to the development of competitive shellfish aquaculture. New Zealand, even though geographically isolated from other problem areas, is not immune to these difficulties. Currently severa! introduced ascidians threaten New Zealand's highly valued shellfish aquaculture industry, andas such efforts to control and manage these species are ongoing. This has led to an increased demand for tools to mitigate the effects of biofouling pests, including knowledge of the biological characteristics of fouling species that underpin management. Avoidance of crop and equipment infection through knowledge of pest inoculation windows is an example of one such management too!. Most pest species have a fixed reproductive season, often regulated by water temperature, during which eggs or larvae are released and dispersed. Industry can therefore manage their activities to avoid deploying vulnerable life-stages (such as mussel or oyster spat) during high risk periods. We recently assessed the reproductive seasonality of the colonial ascidian *Didemnum vexillum,* in arder to determine the duration of the reproductive season of this species and the occurrence and timing of avoidance windows. Weekly recruitment levels were measured and correlated with environmental parameters (water temperature and salinity) over an 18 month period at two locations. Results indicate that although recruitment levels vary considerably betwe en locations they follow a similar seasonal pattern. *Didemnum* recruits were detected between late November 2007 and early July 2008, a period of 7 months, with a recruitment peak in late January to early February 2008. This shows a 5 month period during the colder months (water temperature $< 13°C$) when *Didemnum* populations are not producing larvae. Later we will analyze tissue samples that have been simultaneously collected, to evaluate the utility of determining *Didemnum's* repro ductive seasonality from assessment of larval development. This information can be applied to the management of this species through industry avoidance of spat seeding at high risk periods, to maximize the growth of these vulnerable small size classes before *Didemnum* populations spawn and larvae are present in the water column.

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TEMPERATURE AND SALINITY TOLERANCES OF ZOEA I LARVAE OF AN INVASIVE PORTUNID CRAB, CHARYBDIS JAPONICA, IN NORTHEASTERN NEW ZEALAND: IMPLICATIONS FOR FURTHER INVASIONS

Fowler Amy E., University of Auckland, Leigh Marine Laboratory, Leigh, New Zealand Nadine V. Gemer, Goethe-Universite Frankfurt, Germany

Oral Presentation

The successful invasion of a non-native species depends on several factors, including initial colonization and establishment of a self-sustaining population. Populations of the non-native crab *Char_ybdis Japonica* were first recognized in the Waitemata Harbour, Auckland, New Zealand in 2000, most likely arriving in ballast waters of an Asian merchant vessel. A survey completed in 2003 found C. *Japonica* throughout the Waitemata Harbour, and further sampling in 2008 has revealed several well established populations in estuaries up to 120 km from the putative invasion point. As the potential for further establishment of C. *japonica* beyond this area may depend on the temperature and salinity tolerances of their free swimming larvae, we quantified the survival of first day C. *Japonica* zoea I subjected to temperatures ranging from 5 to 45°C or salinities from 5 to 45 ppt in the laboratory. Upon hatching, replicate C. *Japonica* larvae were directly transferred from 21ºC and 34.6 ppt seawater to either pre-heated filtered seawater at the experimental temperature or one of the salinity values prepared using artificial seawater or filtered rainwater. Behaviour and death rates of the larvae were monitored overa 24 hour period in the absence of food. The results show that C. *Japonica* zoea I tolerate a broad range of temperatures and salinities and can survive natural conditions in northeastem New Zealand. The potential for C. *Japonica* to invade other New Zealand and South Pacific estuaries and harbours will be discussed.

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STATISTICAL CONSIDERATIONS IN ESTIMATING ORGANISM CONCENTRATION IN BALLAST WATER DISCHARGES

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Oral Presentation

Sampling probabilities may affect the practical use of different ballast water performance standards which establish the acceptable concentration of organisms in ballast discharges. The lnternational Maritime Organization (IMO) has initiated a ballast water standard of < 10 viable orgarúsms m-3 for orgarúsms >50 µm. More stringent standards have been considered by others, such as the <0.1 organisms m-3 in U.S. Senate bilis 363/1224 to the <0.001 orgarúsms m-3 based on an analysis ofnatural invasion rates . To accurately estímate the concentrations of organisms at these low levels it is critical to consider issues of sampling probabilit y. For example, given a performance standard of <0.1 organisms m-3 anda true concentration of 0 . 2 m-3 (two times the proposed standard), about 20 m3 ofballast water must be sample to have a 90% probability of detecting this exceedence . Given a performance standard of <0.001 organisms m-3 anda true concentration of0.002 m-3, nearl y 2000 m3 ofballast water must be sampled. I is also possible to fail when the true density is below the performance standard (i.e., false positive). For example, given the IMO performance standard of <10 organisms m-3 anda 1 m3 sampling volume, a ship with a true density of 7 orgarúsms m-3 will appear to exceed the perform anc e standard about 10% of the time. For these calculations, organisms are assumed to be randomly distribut ed in the ballast water (i.e., a Poisson distribution). If organisms are sufficiently aggregated then estimating densities will require sampling larger quantities of water. In the example with a performance standard of 0.1 organisms m-3, by adding an aggregation component (dispersion parameter of 0.5) to the model, the quantity of water sampled must increase from 20 to about 30 m3 to maintain the same probability of det ection. Determininf the distribution of orgarúsms in ballast water to assess the extent of aggregation will be an important step for developing protocols to accurately estímate the concentration of organisms.

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DOES EVOLUTIONARY HISTORY INFLUENCE RECOGNITION OF THE EUROPEAN GREEN CRAB (CARCINUS MAENAS) IN THE NORTHWEST ATLANTIC?

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Poster Presentation

Marine biological invasions bring species into contact that have had no shared evolutionary history. This absence of shared evolutionary history may influence invasive predator impacts, including cascading effects on lower trophic levels that alter prey number (a density-mediated interaction) or prey behavior (a trait-mediated interaction or TMI). In order for TMis to occur, prey must often recognize waterbome cues from the predator. There are several possible mechanisms for TMis to occur in the case of invasive predators: native prey may be unable to detect the invasive predator, native prey may detect the invasive predator regardless of previous experience, or the capacity to recognize the invasive predator may develop as an evolved or acquired trait. Work presented here is the second part of a series to assess the capacity of native whelks to respond to the invasive European green crab *(Carcinus maenas).* We compare foraging behaviors of Northwest Atlantic whelks *(Nucella lapillus)* when exposed to waterbome chemical cues from *Carcinus.* 1bese *Nucella* were taken from populations that are not invaded by *Carcinus* and have never experienced predation from the crab (western Newfoundland), or from populations that are invaded and are known to respond to the crab (i.e. Maine). We found that *Nucella* from both populations respond to waterbome cues from the crab. Thus, even whelk populations that share no evolutionary history with *Carcinus* recognized the invasive crab's waterbome cues. Furthermore, *Nucella* taken from Maine and New Hamphsire had significantly thicker shells than conspecifics from Newfoundland. These results will be discussed in the context of similar studies on *Carcinus'* impacts in the invaded regions of Australia.

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111 :M l(; l APS US SANGUINEUS: REPRODUCTIVE SEASONALITY IN NORTHERN ANO SOUTHERN NEW ENGLAND

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Oral Presentation

Hemi9rapsus san9uineus is a shore crab native to the western Pacific, now considered an invasive species on the east coast ofthe United States. *H. san9uineus* has been present south of Cape Cod since 1988, but was first found in New Hampshire in 1998. This species is not yet as dominant or abundant in northern New England as in Southern New England. Because this species spans a wide latitudinal range, fecundity may vary between populations based on season length and water temperatures during the reproductive season. In order to better understand the seasonal reproductive patterns of this species and how they may vary with latitude, both adult and larval populations of *H. san9uineus* were studied at two sites in New England (Rye, NH and Jamestown, RI) from June to October 2008. Rocky intertidal areas were sampled for ovigerous females, and nearshore waters were sampled for larvae using light traps and plankton tows. Peak proportion of ovigerous females and peak spawning occurred approximately one month earlier at the New Hampshire site than at the Rhode Island site. Peak densities of early zoeae in the water column followed the peak in proportion of ovigerous females at both sites with a lag of approximately one month. Early stage zoeae were the primary life stage of *H. san9uineus* found in all plankton samples, which supports an export and return model of *H. san9uineus* dispersal and development. To further investigate the patterns observed in 2008, intertidal and plankton surveys were repeated in 2009, expanding the timeline to March - October in arder to determine the onset of spawning season at each site. Intertidal surveys were also expanded to collect demographic information for each population, including average female size and size at 50% maturity. Physical parameters (temperature and light intensity) were recorded at each site in order to test for correlations of these factors with reproductive activity.

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N< >N-NATIVE INVERTEBRATE SPECIES IN SUBTIDAL FOULING COMMUNITIES 01: THE BRITISH COLUMBIAN COAST

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1 1r,1l Presentation

< ;lol>ally there are growing ecological and economic concems over non-native species invading natural ,·rn systems. In British Columbia (BC), the Strait of Georgia alone contains over 117 known non-native 111.,rine and estuarine species, yet very little is known about their distribution and abundance along the rest , ,I' the BC coast. In the spring of 2007 an initiative began to examine geographic patterns in invertebrate t,,uling community structure and distributions of non-native organisms along the BC coast. A large rnllaborative project involving marinas, the aquaculture industry, and the Canadian Coast Guard, over 100 sl'ttlement arrays were deployed. Deployment sites spanned a range of coastal environments from the /\laskan border to the southern Gulf Islands, including both the Queen Charlotte Islands and Vancouver lsland. Settlement arrays were hung from floating structures to a depth ofthree meters and were collected llve months following deployment. Sample processing involved identifying all species present in the rnmmunity, their relative abundance, and noting any ecological interactions between native and non-native spccies. Non-native species constituted ten percent of the species identified, primarily in the bryozoan and tunicate taxa. Globally, these taxa are known for their befouling properties and our data has important 1·cological and economic implications. Further, distribution and patterns of non-native species included new rcports of invasive tunicates in the Queen Charlotte Islands. This project was crucial to gaining pertinent information on key non-native species throughout BC waters that can be used to focus monitoring programs and aid in management decisions.

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PROSPECTS FOR WHOLE COMMUNITY MOLECULAR ANALYSIS OF MULTICELLULAR EUKARYOTIC MARINE ORGANISMS.

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Oral Presentation

Monitoring existing assemblages of invasiv pccie or detccting n , in\'a ions in olve a higl work load sample processing: it is easier to collcct large volume · f amples than to sort and identify th pecies therein contained. For many specie , iden tifica tion req uír e a lúgh 1 Yel of Lraining and experti e, and experts are oftcn bac klogged with specimens. For these reasons, more rapid methods of identification would be a b on to m nitoring eITorts. M le cular identificat io n of individual p imen has been freque applied, howe, er costs of conv ntional P R and sequ ncing are relative,l high and throughput is relati low . Whole mmuni · analysis ha the polential to grcatl increa e throughput an<l dramaticall ' lower costs on a p r ample basi , In this approacb, D A from e n tire environmental sample is extracted, targ gene(") amplified by PCR , and the amplicon pool quenced exhausti-vely by next-generation equencio tec:hnolo.., •, Th.i approach, or rnriant hav been adopted in micr o bial ecolog but .car el • o r r mul tice lJ ular ukaryot e hecause of everal concept ual and tedmical imp dimen . 1 e x plor ed sorne of t i sue surrounding tax.onomic bia in ·am pl pro essing prior to next-gen equencing, induding tract eflk ienc, and P R bias. 1 pr e ent data from equen clng of enviro nm nta1 D A from a variet of mar in mi r habitat , including h 11 piobiota and s ttling plates. P R+cl ning+sequcncing of 1 rR ge fragments from heavily n ru t ed ·h 1,1 · icl<led a high di r it y of taxa included ponges, anncHd ·, fun dil rophytes, rh dophyt , and pha oph tes but also a larg e number of bacteria! sequences. Optimizin primer sets largc,l e liminaLe d bacteri a! tcmplatc írom th ainpli on library. th r o stacle to tbe community anal i approach includc the pot ntial lo ss of pecies rep r enta ti \'l. nes w-ith each m lec u lr manipulation. I illu ·trate ·om f the ·e effects with rcsults from marine plan kton from Moor ea and ·et t plat from Hawaii. P R from plankton extractio n · was strongl ' bia · d toward vc r tebrat e equ ence . Howe cr, with con lro lled mixe of tem plates fr m individual ex-traction from rgani m on ttling pl PCR bias wa not ever . While w conti nu e to exp lore p o tential biase · and mean · to cont ro l thcm, w plan to begin nex t- g ncra lion st<1uencing of se ttling plate and plankton ample from an Franci ·co Ba late 2009.

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TEMPERATURE AND SALINITY TOLERANCES OF ZOEA I LARVAE OF AN INVASIVE PORTUNID CRAB, CHARYBDIS JAPONICA, IN NORTHEASTERN NEW ZEALAND: IMPLICATIONS FOR FURTHER INVASIONS

Amy E. Fowler, University of Auckland, Leigh Marine Laboratory, Leigh, New Zealand **Gerner, Nadine V.,** Goethe-Universite, Frankfurt, Germany

Poster Presentation

The successful invasion of a non-native species depends on several factors, induding initial colonization and establishment of a self-sustaining population. Populations of the non-native crab *Charybdis Japonica* were first recognized in the Waitemata Harbour, Auckland, New Zealand in 2000, most likely arriving in ballast waters of an Asian merchant vessel. A survey completed in 2003 found C. *japonica* throughout the Waitemata Harbour, and further sampling in 2008 has revealed several well established populations in estuaries up to 120 km from the putative invasion point. As the potential for further establishment of C. *Japonica* beyond this area may depend on the temperature and salinity tolerances of their free swimming larvae, we quantified the survival of first day C. *japonica* zoea I subjected to temperatures ranging from 5 to 45°C or salinities from 5 to 45 ppt in the laboratory. Upon hatching, replicate C. *japonica* larvae were directly transferred from 21ºC and 34.6 ppt seawater to either pre-heated filtered seawater at the experimental temperature or one of the salinity values prepared using artificial seawater or filtered rainwater. Behaviour and death rates of the larvae were monitored overa 24 hour period in the absence of food. The results show that C. *Japonica* zoea I tolerate a broad range of temperatures and salinities and can survive natural conditions in northeastern New Zealand. The potential for C. *japonica* to invade other New Zealand and South Pacific estuaries and harbours will be discussed.

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MARINE INVASIONS, QUANTIFYING ECOLOGICAL AND ECONOMICAL DAMAGE IN TIME AND SPACE

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Oral Presentation

Biological invasions are fundamentally changing ecosystems around the world. During our studies we focused on quantifying and predicting the amount of ecological and economical damage that is done by marine invaders. To study ecological impact in time and space, a fouling community study was started in 2006, which is planned to go on indefinitely. In this SETL-p roject, ten 14x14 cm PVC-plates per locality are hung one meter below the water surface, and refreshed and checked for species every three months. Along the Dutch coast sixteen localities, varying in parameters like salinity, water temperature and the strength of currents, are monitored. About 15 non-native and 90 native species have been identified on the plates, but more are still to be expected according to a species accumulation plot. The 2006-2009 results indícate that the amount of ecological damage to a habitat can at least partly be linked to parameters like watersystem size, temperature and salinity. This enables us to predict the vulnerability of marine habitats for a vast range of invasive species. In addition, a project that was done simultaneously indicates that similar environmental parameters can be linked to the potential economical damage that is done by invaders. To study this, we have intensively int erviewed close to a hundr ed harbormasters and stakeholders at 55 localities along the Dutch coast. This includes both the people that pay and the ones that are being paid for e.g. cleaning the fouling of floating docks, or for getting rid of Japanese oysters on sandy beaches. To get an estímate of the extra costs linked to non-native species when removing fouling, we recorded the time it took to clean severa! fully overgrown floating docks and piers, which varied in surface cover by native and non-native species. All plants and animals that were found, were photographed and identified to the species level by their morphology, or by D NA-analyses . Relative species coverage was calculated from video, photographs andan 1x1 meter iron frame, dived with fishing line into 14x14 cm squares. On the basis of the interviews, the fieldwork, and the found correlations with environmental parameters, costs were extrapolated and estimations were made of the minimal yearly econo mical costs caused by marine invaders along the Dutch coast and more in general, western Europe. These are under estimat es because costs related to e.g. aquaculture and public health have not yet been taken into account.

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DETERMINING THE PROBABILITY OF NON-NATIVE SPECIES EXPOSURE TO NEARSHORE MARINE HABITATS IN HAWAII

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Oral Presentation

A regional risk assessment approach was used as the basis for an ecological risk assessment for marine non-native species exposure in Hawai'i. The multi-criterion analysis technique, the Analytic Hierarchy Process (AHP), was use for the analysis and the results were displayed through a Geographic ln formation System . The AHP technique is characterized by the description of a decision situation as a hierarchy and by the application of a specific measurement scale to obtain vectors of normalized weights using pair-wise comparisons. The first step in this study was to create a simple categorization of the marine habitats present in the main Hawaiian islands and then identify and prioritize the plausible mechanisms of transport that could expose these habitats to non-native species . The hubs for maritime and air shipping and human-altered shoreline areas had the highest probability of being exposed to non-native species. From a pathway standpoint, the highest priority was assigned to biofouling associated with interisland commercial vessels and private vessels arriving from overseas. Additionally, the legal and illegal transport of live organisms associated with the both the live seafood aquaculture and aquarium industries had the second highest priority as a pathway. This analysis showed that an increase in the transport of live organisms by these sectors increases the likelihood of exposure to natural habitats associated with the coral reef environments in the main Hawaiian islands. The approach that was used in this study was capable ofboth framing the decision situation and conducting an analysis that integrates quantitative and qualitative data.

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MINIMIZING THE TRANSPORT OF MARINE NON-NATIVE SPECIES TOAN ISOLATED MARINE PROTECTED AREA

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Oral Presentation

The Papahanaumokuakea Marine National Monument (PMNM) was created by Presidential proclamation on June 15, 2006. The PMNM is one largest marine conservation areas in the world. It encompasses 137,792 square miles of area encompassing the northwestem archipelago of Hawaii. The extensive marine communities of the PMNM comprise one of the last relatively intact coral reef ecosystems in the world. Baselíne information for marine non-nati ve speci and mecha nisms of transport was developed in 2006 and has been used to develop management ·trategie. . T hi r tce n marine non-native specíes have been recorded in the PMNM, with eleven confírmed to be stabli hed . Thc over 400 marine non-native species recorded from the populated o utb ea te rn portia n of tbe archipelago repr e e.n t the most likely source of invasive pecie · for the PM M based on the pro ximit y and patte rn of mari time activity associated with this portian of the archipe lago . ElTort were b gun in 2006 to minimize the tran port of marine alíen species to the PMNM through a management strategy focused on maritime vessel traffic and associated research and re-supply activities as the primary transport mechanisms. These efforts involve mandatory management steps for ve sel platfor m ai1d focus o n a uite of vec tors that are associated with activities allowed through a permitting ıstem. The goal i· to minimize tbe likeli h ood of marine non-native species transport to the PM M by the. e pcrm i tted ac tivi tie . T he manage men t steps taken and the tools used to accomplish tbe goal w ill be presented.

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HOW TO TAKE A REPRESENTA TIVE BALLAST WATER SAMPLE?

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Oral Presentation

Sampling ballast water of ships is very different compared to water samplings in nature. For scientific and regulatory purposes it becomes more and more relevant to develop sampling strategies resulting in accurate, i.e. representative, results of biota in ballast water. One reason being compliance control samplings with the standards set forth in the Ballast Water Management Convention of the lnternational Maritime Organization and also to proof the effectiveness of ballast water treatment systems onboard vessels. The author sampled ballast w¡¡.ter of more than 200 vessels and has extensive experience in onboard ballast water samplings also including performance tests of ballast water treatment systems. Results from these studies will be reviewed and possible sampling strategies will be discussed. The data will also show the differences and similarities when using different in-line and in-tank sampling points onboard ships.

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THE CONSUMPTION POTENTIAL OF INVASIVE LIONFISH (PTEROIS VOLITANS) ON CARIBBEAN CORAL REEFS

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Oral Presentation

Indo-Pacific lionfish *(Pterois volitans)* have recently invaded and are rapidly spreading throughout the tropical Western Atlantic. These venomous fish use an ambush strategy to consume whole prey, and are now one of the most abundant predators of their size on invaded Bahamian coral reefs. To understand the impact of predation by lionfish on native fish communities and to predict their potential impacts in the wider Caribbean, we studied the diet and habitat selection oflionfish on reefs along the southwest coast ofNew Providence, Bahamas. Data on prey-sized fish density, diversity and size distribution, reef complexity and topography, and lionfish density and habitat preference were collected from 14 sites varying in habitat types, depths and lionfish densities. From January 2007 to July 2008, 500 lionfish (TL = 50 - 424 mm) were also collected from these sites. Stomach content analysis revealed that lionfish prey heavily on many species and size classes of native reef fish. Combining data on lionfish and prey biomass with diet data and experimental rates of prey consumption revealed that lionfish have the potential to remove prey from reefs ata rate far greater than reef fish populations can replenish themselves. Furthermore, lionfish density was positively correlated with both reef complexity and relief, but not prey fish density or biomass. Thus, lionfish have the potential to impact significantly native reef fish communities.

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DIVERGENT IMPACTS ON COMMUNITY COMPONENTS BY AN INVASIVE **ALGA**

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Oral Presentation

In soft-sediment marine ecosystems, marine habitat-farming invasive species (HFIS) frequently facilitate biodiversity and species abundance. Studies commonly highlight positive effects on epibiota to the exclusion of infauna or, when infauna are included, present net positive effects despite evidence far negative impacts on infauna. Because HFIS are strong modifiers of the abiotic environment (e.g. sediment quality), and infaunal organisms are sensitive to environmental change, we may predict divergent responses from different community components, i.e. positive far epibionts and negative far infauna. Here we compare **the** response of different community components in native habitats to invasion by the green alga, *Caulerpa taxifolia*. In agreement with our predictions *Caulerpa* has positive effects on epibiota (both through density and novel trait-mediated interactions) and large negative effects on infauna. Moreover, specific functional groups (filter-feeders) were more affected than others. Negative effects on infauna appear related to *Caulerpa'* s strong impacts on environmental quality (i. e. reduced water column dissolved oxygen and increased sediment sulphides and anoxia) compared to native habitats. Our results indicate that by **ÍO('UHIII** on the response of a single community component or on net community effects, we may be grossly underestimating the impact of HFIS in soft-sediment ecosystems.

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HOW CAN WE USE EXISTING DATA TO PRIORITIZE ERADICATION OF EUROPEAN GREEN CRAB POPULATIONS?

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Oral Presentation

Despite the successful eradication of a handful of invasive estuarine and marine species over the past decade, there is dominant belief in the broader invasiYe species community that eradication is impossible or unlikely in nearshore coastal systems. Admíttedly, sorne groups oftaxa are better candidates that others based a number of contingencies. Here I provide a synthesis of data and ideas regarding the role of population connectivity, degree of spread and establishment, life-history, etc. in the context of current estimates of the costs and scale of eradication. For the European Green Crab *Carcinus maenas,* we know more about these parameters that we do for most other taxa, yet much uncertainty surrounds efforts to manage this species in the western North America. I discuss how particular data could be used to prioritize eradication efforts within the range of species like *Carcinus* and to what degree this framework would apply to similar invasions in this region.

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THE IMPACTS OF SPARTINA INVASION ON COMMUNITY STRUCTURE ANI > ECOSYSTEM FUNCTION IN SAN FRANCISCO, CA ANO WILLAPA BAY, WA.

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Oral Presentation

Plant introductions in estuarine systems can produce substantial changes ranging from species replacl'J\11'111 to broad-scale alteration of ecosystem properties. Here we examine the changes produced by thc invi\Nl1111 of Atlantic smooth cordgrass *Spartina alterniflora* in two Pacific estuaries, San Francisco Bay, CA iln<I Wlll11pn Bay, W A. We compare and contrast benthic invertebrate foodwebs inhabiting invasive Spartina **ml'i\dowN** relative to naturally unvegetated muflats (SF Bay) or relative to mudflats colonized by introducccl /.o.,1rr,1 *japonica* (Willapa Bay). In both bays, we use dual isotopic tracer experiments with δ 15N lalH'li•cl Spartina detritus and δ 13C labeled microalgae as well as δ 15N labeled *Zostera japonln,* detritus in Willapa Bay. At both sites, our results showed similar and substantial shifts in benthic communities including reductions in larger, surface-feeding taxa concurrent with increases in smalh·r, subsurface detritivores. We also found that the uptake oflabeled *Zostera* was significantly greatcr th1111 1'111 Spartina suggesting greater palatability and usage by benthic consumers. Therefore, the food web **Hhll't** produced by Spartina invasion towards smaller and more infaunal species will likely have negatiw l111p,11 , 0n consumer populations including crabs, fishes and migratory shorebirds. We discuss these rcsultN lll 1l1l1 context of introduced plant effects in other estuaries to help develop a predictive framework futurr estuarine plant invasions.

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PACIFIC OYSTERS (CRASSOSTREA GIGAS) IN STRANGFORD LOUGH, NORTHERN IRELAND.

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Oral Presentation

Crassostrea Biaas was introduced into Strangford Lough at licensed aquaculture sites in the 1970s. It was believed that unfavourable temperature conditions would prevent the species from breeding in the wild. In the mid 1990s naturally settled C. *Biaas* were reported in the Lough which may have been facilitated by changes in sea temperature. This research addresses wild populations of C. *Biaas* in Strangford Lough with the aim of investigating its distribution, reproductive cycle and potential impacts on the native biota. To date, the distribution of the species in the Lough has been ascertained as well as the population structure which suggests that recruitment does not occur every year. Survey work is ongoing and a pilot eradication scheme has been initiated. The range expansion of species is a common issue worldwide and has been seen to have major deleterious ecological implications in sorne areas (Simberloff et al, 2005). It is often felt that the establishment of populations of invasive species is partly facilitated by the delay of decisive action whereby the window of opportunity when the populations are small and in a lag growth phase is missed.
The initiation of a C. *Biaas* cull while populations are relatively low is an attempt to take advantage of the lull period before a potential rapid population expansionas outlined by Simberloff (2003). The low population densities lend themselves to the methodology ofhand removal which will minimise the impact on other populations in the Lough. Other methods such as dredging or removal by heavy plant machinery would be inappropriate for an area such as Strangford Lough which is protected by EU legislation. In terms of implications for management in the area it is recommended that C. *Biaas* should culled annually in the attempt to arrest the population increase of this highly invasive species in a globally important ecosystem. In addition, the results of this pilot cull will be used to develop a management strategy for Strangford Lough which may well be applicable elsewhere.

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SEX PHEROMONES: A TOOL FOR CONTROLLING THE GLOBALLY INVASIVE GREEN CRAB, CARCINUS MAENAS?

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Oral Presentation

The European green crab, *Carcinus maenas,* is amongst an increasing number of crustaceans spreading globally as introduced species. Mechanisms to halt the spread of marine invasive species include trapping, poisoning, disease infection, habitat modulation and the use of natural enemies, but none have proven successful. Scenarios developed for terrestrial integrated pest management (IPM) are required to manage or eradicate unwanted species in the marine environment. An element of marine IPM successfully applied to sea lampreys is the use of chemical signals, in this instance a sex pheromone. We examined the potential use of the recently identified female sex pheromone of the green crab, *Carcinus maenas,* to trap conspecific males. We also present the complexity of endocrine, environmental, behavioral and chemical factors that affect the practica! use of sex pheromones in aquatic pest control and evaluate possible scenarios that can potentially be used to manage crustacean species in the field.

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INTRODUCED SPECIES SUCCESS: THE INTERACTION OF OVERFISHING AND MAN-MADE STRUCTURES

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Oral Presentation

The success of species introductions into new environments is a global problem, which appears to be facilitated by the perturbations caused by anthropogenic habitat modification and overfishing. Previous studies have suggested that communities that colonize pier pilings can be influenced by benthic grazers and predators when they have access to these man-made structures. Observations of communities occupying pier pilings in Herradura Bay, Coquimbo, Chile suggested that grazing by the sea urchin *Tetrapygus niger* and the large rock shrimp *Rhynchocinetes typus* were strongly influencing community structure relative to pilings isolated from these grazers by sandy bottom with no refuges from fish. Quadrat sampling of piling communities showed a gradient of pilings dominated by crustose coralline algae (urchins) to pilings with a cover of turf algae (shrimp) to a dense cover of the introduced bryozoan *Bugula neritina.* We performed a 3-month field experiment to examine the grazing effect of sea urchins and rock shrimp on piling communities utilizing inclusion and exclusion cages. The treatments included no predators, inclusion of urchins, shrimp and shrimp and urchins. The results showed strong effects by both urchins and shrimps on piling communities. In cages with urchins, bare space dominated, while cages with shrimp resulted in cover by turf algae and exclusion cages developed a dense cover of bryozoans and the tunicate *Ciona intestinalis.* Both *Tetrapygus niger* and *Rhynchocinetes typus* have elevated populations where fishing pressure is high and likely assume a major role in structuring benthic communities. The results of this study suggest that native predators in natural benthic communities may inmbit establishment of introduced species, which would explain why marine invasions tend to be most common in highly altered coastal environments with extensive human development and removal of upper trophic level predators.

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MOLECULAR DETECTION OF MARINE INVERTEBRATE LARVAE AND MAJOR COPEPOD GROUPS IN SITU USING ROBOTIC DEVICES DEVELOPED AT THE MONTEREY BAY AQUARIUM RESEARCH INSTITUTE (MBARI).

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Oral Presentation

Rapid, accurate identification of invertebrate larvae and other microfauna from environmental water samples has long been a "holy grail" for marine ecologists, microbiologists and population geneticist·s striving to better understand dispersa! dynamics, recruitment processes and genetic connectivity among subpopulations of organisms . Additionally, the ability to assess local environments for the presence of reproductive propagules from potentially invasive alien species represents an invaluable resource for ecosyst m monitoring and management efforts. While molecular methods offer high throughput screening capabilities and accurate detection of specific **DNA** or **RNA** sequences from complex environmental mixtures, problems exist with sampling standardization, assay robustness and repeatability. To address these problems while performing consistent monitoring of waters in California' s Monterey Bay, we have created 18S ribosomal RNA targeted probes capable of detecting a variety of invertebrate larvae and copepod groups. Using a taxonomically hierarchical approach to probe development has allowed us to detect groups of organisms at varying taxonomic scales (crustaceans, polychaetes, crabs, bamacles, calanoid and podoplean copepods, and the mussel genus *Mytilus)* as well as specific taxa such as the European green crab, *Carcinus maenas.* The two probe sandwich-hybridization assay (SHA) is a robust system that has been developed for stationary and mobile sampling formats. In situ sampling and molecular detection is accompHshed with MBARI' s Environmental Sample Processor (ESP). This robotic laboratory, deployed on a mooring, contains printed microarrays of molecular probes and all the reagents necessary for on-board processing of the environmental samples, resulting in near real-time detection of microorganisms. In contrast, the Autonomous Underwater Vehicle (AUV) is a mobile, autonomous sampling device that collects a wide array of physical data (allowing for the detection of specific oceanographic features), in addition to water samples. Molecular analyses are then performed at our shore-based laboratory. While the two systems represent majar advances in environmental sampling, our molecular methods are universal and therefore equally accessible to researchers regardless of sampHng method. With respect to invasive species monitoring, SHA chemistry is quite resilient to sample variability, making it broadly applicable to a variety of samples whether from ballast water, estuarine, neritic, oceanic or fresh water environments. Furthermore, our work has major implications for answering key questions regarding biodiversity, population genetics, food-web ecology and fisheries science.

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PROPAGULE PRESSURE, PREDATION ANO INVASIVE SUCCESS

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Oral Presentation

ln \'ash •e propagule p re ur e de cribes the ani,·al para meters of a species released into an area in which it is not native. tudic f propagule pre ··ure in gra lands, freshwater fish, birds, mice and ungulates provide el r e vide nce for a po itive r elation ship berw en increasing propagule pressure and invasion success. However,, e know üt tle of the fmportance of propagule pressurc relative to other inva ibilít y preclictor (e.g. di tw·bance and t.Üversitv). tudying the interaction between 'inva ion preCÜctor ' and propagule pres ure wm pro vid e u with a more realistic mod 1 of how inv asive pecies are able to coloni e and persi t in ne w hab it a ts. [n particular there is a paucity of manipulati ve expcrimen t amining propagul pre ure and in\'a ion ucce sin marin ı tem ·. In thc e •stems, propagule pres ure gen rall r fers to the r lease of early life histor y ·tages of organi m (e.g. larvae) which are typically cüfficu lt to manipulate. In the cur rent stud ' we exa mine the role of pr dat ion in fac:ilitating the r cruitment and per ·is tence of the invasive Pacific O•ster, *Crassoscrea 9i9as.* e iodepencle ntly manipulated propagule pressure (oyster larvae) and preclation in the field. emb lages of . e sile im ert ebrates were subjected to exposure to three different concentration · of in,·a·ive oy ter lar \'ae . ln cr easing propagule pressure increased initial invasion ucc:e ·, but pre<lation had trong effec t on the persi tence of the invasive recruits within the hard substrate community.

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CONSIDERATIONS FOR THE DEVELOPMENT OF A RISK FRAMEWORK FOR MARINE BIOFOULING

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Oral Presentation

A number of differing human mediated vectors are capable of transporting marine species. Much attention has been focussed on ballast water with development of international, regional and national responses now in place. Marine biofouling, specifically of vessel hulls, has now become the focus for intemational efforts. Here we focus on the development of a biofouling risk framework with application to the Australian context. Risk assessment is increasingly becoming a tool for environmental management comprising both the likelihood and consequences of an event such as the invasion of a species. Key hazards were considered by the Australian government to be those species with a recognised invasion history and not present in Australia. Through previous work, we have identified more than 1780 species identified as being introduced to sorne region of the world. Likelihood of transfer to Australia was calculated as a function of the likelihood of a species association with biofouling coupled with its transport pressure. Species association with biofouling was assessed based on life history characteristics, representing 745 species, of which 550 are not present in Australia. Transport pressure was calculated as a function of the intersection between a species' global distribution and the opportunities for transport calculated as a combination of the number of vessels arriving in Australia from regions where a species is present and vessel characteristics including size, speed and residency period in port. Vessel biofouling represents an accumulation of species starting shortly after dry-docking. Unfortunately data is not readily available on date of last dry-docking, consequently we evaluated vessel behaviours overa five year period (2002-2007) with an assessment of increasing voyage durations to determine the number of regions visited. The consequence or impact a species will have once it arrives in Australia, Consequence (or impact) was assessed across four core values of environment, economic, social and human health for each species based on information derived from the literature. The vast majority of species did not have either demonstrable or inferred impacts stated in the published literature creating a significant limitation to the application of risk assessment. For those species with consequence information, risk was calculated as the product of likelihood and consequence resulting in a suite of species for consideration by government authorities.

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THE INTRODUCTION ANO DISPERSAL OF INTRODUCED SPECIES INTO OFFSHORE WATERS

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Oral Presentation

Non-indigenous species (NIS) are now widely recognised asan issue of global import, with many marine invasions recognised in all coastal regions of the world's oceans. We indicate our concerns about the appearance of non-indigenous species offshore and in deeper waters and we make a prediction that following the opening of the seasonal shipping route following Arctic sea-ice retractions following alterations in climate further such invasion events are likely. Many biologists will be aware of examples of non-indigenous expansion to offshore regions. However, we note that this is happening on a global scale. We have drawn-together examples of different taxa that have been dispersed by various human activities, including sorne that have already caused significant environmental or economic impacts. A general belief that deep and offshore waters are protected from human impacts leads researchers not to expect NIS offshore and we believe that the presence of NIS in these waters needs to be more widely known and investigated. The increasing use of offshore waters for exploitation activities (aquaculture, fishing, energy, mining etc .) and disposal (ballast water, sediment discharges, decommissioned vessels etc .) are likely to enhance the spread of NIS. W e believe such spread is likely to continue given the current leve! of human mobility and exploitation of marine resources. Precautionary management measures need to be considered by different industries involved in marine activities in arder to reduce the risk of NIS transmissions.

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RESTORATION OF HABITAT FUNCTION FOR MOBILE FAUNA FOLLOWING ERADIATION OF AN ECOSYSTEM ENGINEER: A CASE STUDY OF SPARTINA ALTERNIFLORA AND CANCER MAGISTER IN WILLAPA BAY, WA.

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Oral Presentation

Invasive aquatic macrophytes modify structural complexity in recipient systems and often alter the flow of nutrients and availability of trophic and physical resources. In Willapa Bay, Washington, USA, invasive cordgrass, *Spartina alternif].ora,* had colonized unstructured littoral habitats and converted these areas into highly structured meadows. Unstructured mud and sandflats are important foraging habitats for subadult Dungeness crab, *Cancer ma9ister,* and prey in these habitats contribute disproportionately more to population energy demands than other estuarine habitats. Spatial analysis of *S. alterniflora* coverage in the bay showed that >25% of potential crab foraging habitats had been invaded by 2004, yet by 2007 most of the cordgrass had been eradicated. In arder to investigate the impact of live and removed *S. alternif].ora* on crab foraging behavior, we conducted trapping surveys at multiple sites prior to baywide eradication of the cordgrass (2001, 2002, and 2004) and following *S. altemif].ora* removal (2007). Prior to removal of *S. altemif].ora,* catches of C. *ma9ister* in baited traps placed within patches of live *S. alternif].ora* were 3 - 7 times lower than catches from adjacent unstructured mud flats. Subsequent laboratory experiments and video observations suggested that the rigid physical structure of *S. alternif].ora* shoots reduced the ability of C. *ma9ister* to access prey resources and increased the risk of stranding. The results of post-eradication trapping in 2007 indicate equal catch rates of C. *ma9ister* in open mud and formerly invaded *S. altemif].ora* habitats once the aboveground biomass of *S. alternif].ora* has been reduced or removed. Taken together, these findings suggest that eliminating the structural complexity of *S. altemif].ora* may quickly restare access to littoral foraging areas used by migratory predators like C. *ma9ister*. However, successful restoration of *S. altemif].ora* invaded areas may also depend on the removal ofbelow ground rhizomal biomass, which could continue to impact physical and biotic characteristics of invaded areas and dependent ecological communities.

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SUBTIDAL INTERACTION BETWEEN TWO INVADERS: FIELD BEHAVIORAL ANALYSIS BETWEEN THE ESTABLISHED EUROPEAN GREEN CRAB, CARCINUS MAENAS, AND THE ASIAN SHORE CRAB, HEMIGRAPSUS SANGUINEUS IN LONG ISLAND SOUND, CONNECTICUT, USA.

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Poster Presentation

The invasion of the W estem North Atlantic coastline by the European green crab *Carcinus maenas* in the early 19th century followed by the subsequent invasion by the Asian shore crab *Hemigrapsus sanguineus* allows for a unique opportunity to study the interaction between these species in their use of shelter. With the ensuing invasion of other areas of the world by both of these species or their congeners, this interaction will have relevance. We observed exclusion of C. *maenas* from the littoral zone, with dominance of the littoral zone by *H. sanguineus*. To help answer the question of whether the exclusion of C. *maenas* is behaviorally mediated, we deployed artificial shelters in the immediate subtidal zone in eastem Long Island Sound (Connecticut). Field behavioral analysis consisted of quantification of subtidal use of shelter with the presence of a conspecific and heterospecific in two artificial shelter sizes. W e found both of these invaders will interact with these behavioral apparati, but that *H. sanguineus* is likely present at lower subtidal densities than previously thought, or more patchily distributed. We also found sorne seasonal component within the interaction, with *H. sanguineus* adults present in the subtidal zone at colder timepoints.

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EARLY DETECTION, DELIMITATION AND RESPONSE TOAN INCURSION BY THE MEDITERRANEAN FANWORM, SABELLA SPALLANZANII, IN NEW ZEALAND

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Oral Presentation

The difficulties of direct observation in marine environments and broad dispersa! capability of marine species make early detection, containment and treatment of marine pest incursions challenging. A consequence is that there is often pessimism about the likely success of active surveillance and control attempts for marine pests. New Zealand has hada national surveillance programme for eight harmful marine species in place since 2002. In March 2008, one of those species - the invasive giant fanworm, *Sabella spallanzanii* (Gmelin, 1791) - was detected by the programme in the port of Lyttelton. We describe the two-stage survey design that was used to detect the incursion and then to define its extent and guide on-going treatment. In the surveillance programme, primary survey units were allocated throughout the port using a systematic survey design to detect clusters of fanworms. Scientific divers searched a proportion of habitat available in each primary unit to determine presence or absence of fanworms. Where detected, commercial dive operators then searched all habitat units (secondary units) within the infested primary unit and surrounding units to define the extent of each cluster and remove the worms (i.e. undertake an initial treatment). A range of in-situ tests of the sensitivity of the search and removal method were implemented. These included: (1) deployment and recovery of fanworm mimics, (2) independent searches of treated areas by separate dive teams, and (3) repeat inspection of potentially infested wharf piles after they had been removed from the water. To date, a total of 143 individual worms have been detected and removed from the port. The two-stage sampling design revealed a highly-clustered population, with most (80%) individuals recovered from a single shipping berth and the remainder scattered over a larger area of the port. The initial treatment survey recovered most (73%) of the individuals, which were generally large, reproductively mature worms. Subsequent surveys have recovered substantially fewer worms for equivalent search effort and have documented a marked shift in the size of individuals recovered to fewer, smaller worms. The treatment programme is predicated on the potential to suppress recruitment of *S. spallanzanii* by removing most of the adult population to reduce fertilization success. While early results are encouraging, our efforts highlight deficiencies in our knowledge of the demography and mínimum viable sizes of small marine populations.

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PREDICTORS OF SUPPLY AND ESTABLISHMENT OF NON-INDIGENOUS FOULING SPECIES

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Oral Presentation

The relationship between propagule supply and the likelihood of establishment has been difficult to define for marine pests because of challenges in measuring rates of supply of successful and unsuccessful invaders. We describe the results of statistical modeling, using boosted regression trees, to identify predictors of the extent, frequency of transport, and likelihood of establishment of non-indigenous species transported as biofouling to New Zealand. The study utilized data collected as part of a MAF Biosecurity New Zealand funded survey of biofouling on nearly 500 international vessels that arrived in New Zealand between 2004 and 2006. The sample included 182 prívate yachts, 50 cruise liners, 261 merchant vessels and 3 fishing vessels. Fouling organisms on each vessel were sampled by diver using a standardized methodology and were identified by taxonomic specialists to the lowest possible unit. Each non-indigenous species was also classified according to whether it was known to be established, or not, within New Zealand coastal waters. One hundred and twenty three non-indigenous species were identified, 87 of which were not established in New Zealand waters. Potential predictors of carriage and establishment were derived from: (a) a questionnaire completed by the master of each vessel that detailed information on the vessel's design, maintenance record and recent voyage history and (b) supplementary information on the biogeography **and** life-history of the organisms.

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OBSERVATIONS OF THE PACIFIC OYSTER (CRASSOSTREA GIGAS) IN NORWAY - ALONG A FJORD-SKERRY COAST AN EXPECTED INVASION IS EASILY MISSED

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Oral Presentation

Norway has a rather low number of non-indigenous marine species. Up to 2008, only a few specimen of the pacific oyster *(Crassostrea 9i9as)* had been found along the southern and western coast of Norway. Reports on a limited establishment along the Swedish W coast ("upstream" Norway) was known, and fmdings of more individuals were expected. While no dedicated program to detect Pacific oyster was established, it was assumed that new introductions could be detected in field sites regularly visited by the University of Oslo and the Institute of Marine Research. In 2008, when a national program far mapping and validation of marine habitats was initiated, 12 new locations with Pacific oyster were found scattered along the coast of SE Norway. Three of these had more than 500 oysters, which range in size from 2-1O cm, indicating several generations. The highest density was 1-2 specimen / m^2. The dominant substrate of all locations where blue mussel-beds, and the maximum depth far the observations were about 1 m. According to experience from the western coast of Sweden, one can expect a majar increase in the populations of pacific oyster during the next 3-5 years.

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OCCURRENCE OF HALOPHILA NIPPONICA ON THE COAST OF KOREA RELATED TO GLOBAL CLIMATE CHANGE

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Poster Presentation

The Korean is located in the temperate zone on the eastem extremity of the Eurasian continent. Eight temperate seagrass species (five in the genus *Zostera,* two in the genus *Phyllospadix,* and *Ruppia maritima)* have been previously reported in coastal waters off the Korea, which lies between 33oN and 43oN. Recently, a species of *Halophila,* which occurs predominantly in tropical and subtropical areas, has been observed on the southern coast ofKorea. We measured morphological characteristics, density were monitored monthly from January 2008 to February 2009. The *Halophila* meadow at the study site covered an area of about 21,390m 2. The plants grew in dense mono-specific stands, or occasionally in a mixture with *Zostera marina*. Average shoot density of *Halophila nipponica* was 3,729±412 m-2 and did not show an obvious seasonal trend. However, blade length exhibited obvious seasonal variation, decreasing during fall and winter, and increasing during spring and summer. Water temperature has been monitored every moming at 10:00 ata National Fisheries Research & Development Institute buoy station about 7.5 km south of the study site. Average water temperature during the coldest month (February) on the southern coast of Korea has increased by 2oC during the past 70 years, and thus the average winter water temperature at the study site nmv exceeds 1OoC. Thus, increased water temperature in the coastal waters of Korea may facilitate the persistence of the *Halophila* meadow at the study site. Since the lower temperature limit for the distribution of this *Halophila* species is reported at about 1O oC, the establishment of this tropical seagrass tied the warm Kuroshio and Tsushima Currents into Korean waters can be conjec tu red only a few years ago when average mínimum water temperature of > 10 oC.

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DISSECTING THE DYNAMICS OF HISTORIC INVASIONS: SOURCES AND SPREAD OF THE NORTH AMERICAN INVASION OF THE EUROPEAN ROCKWEED FUCUS SERRATUS.

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Presentation

Past invasions can often shed light on modero situations (e.g., pathways, vectors), especially when detailed records can provide critical information on the establishment and spread of invaders. The quasi-simultaneous discovery in the mid-1800s of two common intertidal species, the periwinkle *Littorina littorea* and the rockweed *Fucus serratus,* in Pictou, a port located in the southern Gulf of St. Lawrence, suggests a common mode of invasion, most likely trans-Atlantic shipping to this one-time major port. An examination of historical records of shipping activity, a proxy of propagule pressure, into Pictou has identified 832 ships from 81 potential source ports in the British Isles, primarily in western Scotland, from which the introductions could have occurred during the period of 1773-1861. Genetic analysis of *F. serratus* from European and North American locations has demonstrated that there actually were two invasions in the l 800s, one at Pictou and another in Cape Breton Island (CBI). Although both invasions originated as predicted from the British Isles, predictions were less precise at finer scales - the CBI invasion did originate from the most probable source (western Scotland) whereas the Pictou invasion originated from Galway, Ireland, a port from which no ships were known to have directly come to Pictou. Recent field surveys suggest that competitive displacement of native fucoids by *F. serratus* is occurring, but also indicate that natural spread over the subsequent 150 years is still limited to the Canadian Maritimes. However, the satellite populations established more recently in Atlantic Nova Scotia suggest on-going human mediated spread. The unusual range retraction from northern New Brunswick and western Prince Edward Island documented in the early 1970's appears stable although the underlying mechanism remains unknown.

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OPTIMAL DETECTION METHODS FOR INVASIVE SPECIES: MONITORING THE DISPERSAL AND RECRUITMENT OF THE TUNICATE CIONA INTESTINALIS IN PRINCE EDWARD ISLAND, CANADA

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Oral Presentation

Discrete, nascent populations of AIS provide opportunities to examine spread immediately following establishment and may provide valuable insight into dispersa! potential and likelihood of natural spread to other waters. *Ciona intestinalis* was first detected in Boughton River, Prince Edward Island (Canada) in late 2007. A grid of 96 settlement plates was deployed in the river in 2008 to monitor recruitment of C. *intestinalis* within and outside the river. Surveys before recruitment identified localized areas of source populations within mussel farms, which were then compared to recruitment across the grid. Initial results indicate that areas ofhigh recruitment did not correspond to areas ofhigh adult abundance although highest levels oflarval settlement were found on plates located within the mussel farms. However, spatial patterns of recruitment shifted during the reproductive season, but no recruitment was ever observed outside of the river. These results suggest that dispersa! is maximal over intermediate spatial scales (O.1-1 km) and is likely influenced by circulation, larval behaviour and habitat features. *Ciona intestinalis* appears currently unable to naturally disperse outside of the river, which suggests the potential for inter-bay spread to occur naturally is low, at least in these initial stages of the invasion. Future work will focus on incorporating a circulation model and larval behaviour to develop predictive dispersa! models for invasive tunicates. This knowledge of the factors influencing post-establishment spread will then be used to develop optima! strategies for future monitoring.

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EXPERIMENTAL MANIPULATIONS OF PROPAGULE PRESSURE AND OTHER INVASIBILITY PREDICTORS

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Presentation

Propagule pressure describes a measure of the number of individuals released into an area to which they are not indigenous. In marine systems this is commonly represented by the release of early life-history stages such as larvae. Despite a long history ofresearch in supply-side ecology, there are few studies that have manipulated invasive propagules in order to gauge community invasibility. W e test the invasibility of marine sessile invertebrate communities by exposing them to controlled numbers ofmobile larvae. Using this technique we examine the importance of propagule pressure relative to other invasibility predictors. Results of experiments examining interactions between propagule pressure, predation, physical disturbance and pollution will be presented.

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COMPARATIVE PHYSIOLOGY OF THE INVASIVE DECAPOD CARCINUS MAENAS, THE EUROPEAN GREEN CRAB

Kelley, Amanda L., Portland State University, Portland, OR, USA

Poster Presentation

In our increasingly modernized world, biological invasions have reached pandemic proportions, escalating biological homogeneity within and among ecological communities worldwide. The effects of biological invasions are manifold. Such invasions dramatically alter ecosystem function and annually cause billions of dollars worth of economic damage within the United States alone. As a result, there is an increasing interest in predicting the spread of established bio-invaders. These predictions would inform strategies designed to minimize the spread of invasive species, determine ideal monitoring sites far their early detection and facilitate eradication efforts. One of the most prevalent invasive invertebrates is the European green crab, *Carcinus maenas,* which is native to the Atlantic from northern Africa to Europe, and has inYaded many different regions globally. *Carcinus maenas* is both eurythermal and euryhaline, and thus inhabits intertidal and subtidal zones, rocky coasts, soft bottom estuaries, embayments and marshes within its home and recipient ranges. To date, there is little known about the physiology of C. *maenas* from invasive populations. Invasive species arrive in new environments with genomes shaped by natural selection and other evolutionary processes that occurred within a different geographic region. Selection far physiological and other phenotypes that are favorable within the new environment operates on two time scales. First, adaptive phenotypic changes can occur within an individual's lifetime, and it is likely that such phenotypic plasticity is essential to the initial success of biological invasions. At the second time scale, intergenerational adaptive changes can occur through selection far more efficient physiological machinery. I will compare the physiological responses to temperature of C. *maenas* sampled from the northern and southern edge of their invasive range on the east coast of the United States. This will determine whether physiological differences exist between subpopulations. These divergent environments may give each invasive subpopulation a site-specific physiological profile that in turn, may encourage long-term adaptive change.

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THE EFFECT OF TEMPERATURE VARIABILITY ON LARVAL RECRUITMENT AND COMPETITION BETWEEN INVASIVE AND NATIVE SPECIES IN ELKHORN SLOUGH, CALIFORNIA

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Poster Presentation

Climate change can alter the community structure as species adapted to the changed climate can compete better with other species. It can also influence the recruitment and invasion success of marine introduced species. We explored this possibility by testing if temperature variability influences the invasion of marine species using fouling community in Elkhorn Slough, California. First, we analyzed the previously collected data to determine if there is correlation between high temperature and invasion success. Indeed, there was tendency that invasive species are dominant in the region under higher temperature. Thus, we conducted a recruitment experiment by putting recruitment tiles in 14 different sites with various temperature gradients. Additionally, to test if temperature variability per se influences the invasion of exotic species, we deployed a shading device for recruitment tiles and compared the species frequency and coverage between shaded and non-shaded treatments. The results suggest that higher temperature facilitates the success of species invasion in the intertidal region.

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INVASIVE SPECIES CAUSE LARGE-SCALE LOSS OF NATIVE CALIFORNIA OYSTER HABITAT BY DISRUPTING TROPHIC CASCADES

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Oral Presentation

Although invasive species often resemble their native counterparts, differences in their foraging and anti-predator strategies may disrupt native food webs. In a California estuary, we showed that regions dorninated by native crabs and native whelks have low mortality of native oysters (the basal prey), while regions dorninated by invasive crabs and invasive whelks have high oyster mortality and are consequently losing a biologically diverse habitat. Using field experiments, we demonstrated that the imasive whelk's distribution is causally related to a large-scale pattern of oyster mortality. To determine whether predator- prey interactions between crabs (top predators) and whelks (intermediate consumers) indirectly control the pattern of oyster mortality, we manipulated the presence and invasion status of the intermediate and top trophic levels in laboratory mesocosms. Our results show that native crabs indirectly maintain a portion of the estuary's oyster habitat by both consuming (density-mediated trophic cascade) and altering their foraging behavior (trait-mediated trophic cascade). In contrast, invasive whelks are na ve to crab predators and fail to avoid them, thereby inhibiting trait-mediated cascades and their invasion into areas with native crabs. Similarly, when native crabs are replaced with invasive crabs, the nai've foraging strategy and smaller size of invasive crabs prevents them from efficiently consuming adult whelks, thereby inhibiting strong density-mediated cascades. Thus, while trophic cascades allow native crabs, whelks, and oysters to locally co-exist, the replacement of native crabs and whelks by functionally similar invasive species results in severe depletion of native oysters. As coastal systems become increasingly invaded, the rnismatch of evolutionarily based strategies among predators and prey may lead to further losses of critical habitat that support marine biodiversity and ecosystem function.

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AN ASSESSMENT OF THE INVASIVE SNAIL ASSIMINEA PARASITOLOGICA'S SPATIAL DISTRIBUTION AND ASSOCIATED HABITAT CHARACTERISTICS IN COOS BAY, OREGON

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Oral Presentation

Assiminea parasitolo9ica, an invasive snail from Japan, occurrence was first documented in Oregon's estuaries in the summer of 2007. *A. parasitolo9ica* was found in the upper mesohaline sections of *Coas* Bay, Oregon in densities estimated at thousands of individuals per meter squared. This finding catalyzed a rapid response short term study to examine *A. parastiolo9ica* within Coos Bay, Oregon. The study was designed to assess the spatial extent of colonization, examine potential species interactions and to observe habitat use. In the summer of 2009, we conducted a rapid assessment of the invasion of *A. parasitolo9ica.* Utilizing modem mapping and surveying techniques we applied both systematic and random sampling strategies to determine spatial extent of colonization. We present both our sampling strategy and our findings on distribution and relative abundance of *A. parasitolo9ica* and associated habitat characteristics.

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l;IRST PACIFIC RECORD OF THE NORTH ATLANTIC ASCIDIAN MOLGULA CITRINA - BIOINVASION OR CIRCUMPOLAR DISTRIBUTION?

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Oral Presentation

The small brooding ascidian *Mol9ula citrina* Alder and Hancock, 1848 has long been known as a common inhabitant of shallow waters on both sides of the north Atlantic on subtidal natural hard substrates and also as a fouler of floating docks. There are published records from the White Sea (NW Russia), but none from the north Pacific. In May and August 2008 a number of adult specimens were collected from floating docks at the small fishing village of Seldovia on the Kenai Peninsula at Kachemak Bay, Alaska. Morphologically these individuals exactly match Atlantic specimens of *Mol9ula citrina* in all characters. The unique constellation of characters for this species differentiates it from all other *Mol9ula* species, as was noted by Van Name (1945). In addition, the full-length 18S and 28S rDNA sequences are nearly the same for both the Alaska specimens and New England *M. citrina.* Is this a new invasion, or is *M. citrina* another of a number of northern circumpolar ascidian species that somehow got overlooked? If this new record indicates a natural distribution, why has it not been collected before now? The north Pacific is a vast region, with many thousands of miles of undersampled coastline especially in northern British Columbia, Alaska, and NE Russia, and thus its invertebrate fauna and distributions are still poorly known . lf it is a recent introduction, it is unlikely that *M. citrina,* an inhabitant of cold waters, could survive in sea chests of ships from the N. Atlantic arriving in Alaska via the Panama Canal, but the intriguing idea exists of transport from Atlantic to Pacific through the Northwest Passage. The tadpoles of this small brooder are retained for sorne time after hatching, resulting in an extremely short free larval life, but could survive as metamorphosed juveniles attached in sea chests or free-floating in ballast water. They have a wide temperature tolerance and once tl1ey metamorphose can live free-floating in sea water for weeks. They become very sticky and will ultimately stick to whatever they contact (BJS, pers. obs.). Thus they could conceivably live for many generations in sea chests and sustain a viable population from which to invade new habitats. As global warming increasingly diminishes the ice cover in this region, more and more ships are traversing the Northwest Passage across northern Canada and represent a significant new route for anthropogenic transport of marine species.

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ASSESSMENT OF SUCCESS: CAN WE ATTRIBUTE A REBOUND OF NATIVE SPECIES TO THE REMOVAL OF THE EUROPEAN GREEN CRAB, CARCINUS MAENAS?

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Oral Presentation

A key objective of invasive species management is the rebound of native communities. With multiple factors affecting species how can we assess levels of success linked to invasive species control efforts? We have been conducting a control effort of the European Green Crab *Carcinus maenas* in Bodega Harbor, California since 2006. Populations of C. *maenas* have shown a decrease of 73 - 85% since we have begun our removal effort . To identify the extent to which any recovery of clam and crab populations can be attributed to the removal of C. *maenas* , we have been conducting a series of predation experiments and monitoring relative abundance of key species. *Carcinus maenas* were kept in containers placed in situ as individuals and at different densities with prey species. We used predation rates from our experiments to determine estimated pre y removal of native species from the harbor. Estimates suggest that had we not removed the 12,794 C. *maenas* in the first year of our intensive removal effort, those crabs could have consumed the equivalent of approximately 922,000 small nut clams *(Nutricola* spp.) or the equivalent of about 28kg, 13,000 striped shore crabs *Hemi9rapsus ore9onensis* or 12,794 juvenile Dungeness Cancer magister in one day. At these rates, given the relative abundance of *H. ore9onensis* and of C. *maenas* present in pitfall trap data collected for 15 years, it would have taken C. *maenas* a median of 4. 7 days to consume all of the *H. ore9onensis* represented in the traps. Clearly, even if containers yield an artificially high level of predation, it is apparent that C. *maenas* consume a large number of prey. These results provide an upper estimate of the amount of prey that would have otherwise been unavailable to shorebirds to the Dungeness fishery had these invasive crabs remained in the harbor. Translations of these predation rates into caloric intake will provide a broadly applicable metric that can be used to predict the impact C. *maenas* has on a community and to predict how that impact will be reduced with reduced C. *maenas* abundance. We discuss how these results compare with the rebound of native species in other systems involving invasive estuarine / marine species.

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Dl:NSITY MATTERS: COMPARISON OF APPROACHES TO DEVELOPING BALLAST WATER DISCHARGE TARGETS

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Oral Presentation

A consensus has evolved that invasion risk increases with propagule pressure. However, translating this general principal into ecologically "acceptable" concentrations of organisms in ballast water has proven challenging. The treaty being promulgated by the International Maritime Organization (IMO) contains performance standards for different size guilds, with a standard of <1O organisms per m3 for organisms >50 microns. To put the IMO standards into context, we are evaluating other approaches to generating ballast water targets. The most protective is the zero discharge standard of organisms > 50 microns being considered by California, though there is a question regarding its technological feasibility in the near term. An alternative California propasa! is to set the invasion rate via ballast water discharges equivalent to the "natural invasion rate". This approach, developed by Dr. Andrew Cohen, is purportedly ecologically protective but ·an initial analysis by experts generated a one-hundred fold range in natural invasion rates. Another low target is the 0.1 organisms per m3 that had been proposed in U.S. Senate bilis, and which appears to be based on expert opinion. Modeling approaches include reaction-diffusion models that predict establishment of an invader as a "race" between the dilution of the population and population growth. Such models are most appropriate to passively distributed organisms that spend their entire life cycle within the water column. Application of this approach by Drake et al. generated acceptable ballast discharge volumes but these were not readily converted to organism concentrations. A more general approach uses population viability analysis (PVA) models that predict the likelihood of extinction (= non-establishment) as a function of the population' s growth rate and population variation. A practica! lirnitation of the PVA models is the paucity of population data, in particular long-term population data to estímate population variability. A final approach is the per capita invasion probability that we are developing based on historie invasion rates. Assuming a linear propagule <lose-response, the per capita invasion probability represents the likelihood that an individual will become established. These various approaches generate "acceptable" ballast water concentrations that vary by orders of magnitude, a consequence of differences in both assumptions and levels of acceptable risk.

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CONSTRUCTING ANO EVALUATING A JOINT OCEANOGRAPHIC-BIOLOGICAL MODEL TO PREDICT THE MOVEMENT ANO DISTRIBUTION OF PROPAGULES ALONG THE EAST COAST OF THE USA.

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Oral Presentation

Propagule pressure is a key determinant of establishment success. In marine systems, the movement of propagules to different locations is logically related to oceanographic currents. Yet virtually no study has validated the extent to which current oceanographic models can be used as a predictive tool to estimate spatially distributed propagule pressures. Here, we integrate existing oceanographic models with ecological spread models (integro-difference models), knowledge of larval behaviour, and empirical data on invasive species *(Carcinus maenas* and *Hemi9rapsus san9uineus).* We illustrate where models are predictive, and identify areas that would benefit from further research.

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ESTIMATING POTENTIAL ANO EFFECTIVE PROPAGULE PRESSURE OF AQUATIC INVASIVE SPECIES IN CANADIAN SHIPPING PORTS

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Oral Presentation

lncreased trade worldwide has created introduction pathways for aquatic invasive species (AIS), particularly through shipping activities. There has been a recent focus on characterizing propagule pressure of AIS in order to manage risks ofbiotic invasion. We used ship arrival and ballast discharge data to provide preliminary estimates of the potential propagule pressure of AIS from ballast water on Canadian shipping ports. We identified annual distributions of ship arrivals in the Great Lakes-St. Lawrence, Atlantic, and Pacific shipping *regions.* We then used these estimates to model the effective (surviving) propagule pressure of AIS on particular ports, after organisms are discharged from ballast tanks. We build on the work of Madsaac et al. (2002) by incorporating an environmental similarity index in the model and parameterizing it with our estimates of potential propagule pressure and mortality rates of various zooplankton species. Model results show that variation in mortality rates may yield high variation in modeled final abundances, and may theoretically determine whether MOE is effective in reducing effective propagule pressure for certain ports or species.

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NATIVE ANO INVASIVE INVERTEBRATE SPECIES COMPOSITION OCCURRING IN EELGRASS BEDS IN MAJOR MARINE PORTS OF CANADA

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Oral Presentation

Fauna! composition within eelgrass beds on the British Columbian and Nova Scotian coastlines has been well studied over the last 50 years. However, species composition is nota static element of coastal ecosystems. These communities undergo regular natural disturbance; water characteristics, wave energy and biological interactions that can cause shifts in community diversity. In addition, anthropogenic disturbance can cause major shifts in coastal ecosystem composition, from over-fishing, nutrient and sediment runoff, coastal de vc lo pment and boating di turbance, cUmate change and introduced specie . With thc potential for majar com mu nity sbift. d uc to natural and human di turbanc , tempora l co mpar i on of . pecies com po ition in Canada' *Zoscera marina* e lgr as bed i important for establishing a hifting ba elio e of ecosyst m hea l th. Eelgrass beds are important for structuring invertebrate commu nitie ancl providing nw-sery ground and shelter for many species of fish. It is essential not only that the ·e b d con tin ue to exist alo ng o ur coasts but that we understand the health of the systems they support. To ana l •ze loc al co mn1 uruty tru ctu re within the *Z. marina* eelgrass beds, I sampled18 eelgrass beds on the Paci6c and Aliantic coa of anada for infaunal, epifaunal and mobile macroinvertebrates. I used this data to compare native and invasive species diversity and abundance between sites on each coast and to look at patterns across coasts. I am comparing this data against species patterns found in similar and adjacent regions and to look at pattern changes across time. In the future i váll be using this data to test the extent to which various impacts (i.e. abiotic, biotic, boating disturbance, and ballast water) on these eelgrass beds explain invasive species composition, diversity and abundance within and between eelgrass beds on Canada's coasts. The ecological pattems described in this study have important implications since they provide a new baseline for future research and can be used to compare to studies over the last 100 years. Understanding these patterns is important especially for communities dependent on threatened habitat, as those invertebrates living in *Z. marina* eelgrass beds are in the Strait of Georgia and on the outer coast of Nova Scotia. Without such data it would be difficult to assess changes to ecosystems, whether dueto human impact or natural variation.

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OETECTION ANO QUANTIFICA TION OF PLANKTERS BY QPCR, THE BRINE SHRIMP AS MOOEL ANO EXPERIMENTAL CONTROL

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Oral Presentation

The brine shrimp *Artemia.franciscana* was used as a model zooplankter to explore the range and accuracy of quantitative PCR (QPCR) in detecting a target species in plankton community DNA samples. Probes were designed in cytochrome coxidase subunit I and 18S ribosomal RNA genes. These were sensitive in detecting *Artemia nauplii* in DNA extractions from bulk plankton. Because QPCR could detect 10/\-5 of one nauplius large plankton samples can be analyzed ata dilution that prevents PCR inhibition. The technique proved equally reliable and accurate using different genes and detection chemistries (SYBR Green I and TaqMan) demonstrating that QPCR does holds great promise for reliable environmental detection and even enumeration of rare mesoplankters! We aim to employ the *A.franciscana* system as a means of setting a quantitative baseline in studies of other organisms, using the DNA mass of the nauplius as a constant, thereby removing uncertainty in making measurements with unknown DNA extraction efficiency.

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STRANGERS ON BOATS: HIDDEN TWISTS IN BRYOZOAN INVASIONS REVEALED BY GENETIC (COI) ANALYSIS

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Oral Presentation

Introductions of fouling organisms, includíng many bryozoan species, are rapídly changing shallow water communities. Mítochondrial DNA has been useful in demonstrating the díversity of invasive species and dynamics of spread and suggests we are underestimating species diversíty from a taxonomic and functional perspective. This presentation will díscuss the results of genetic diversity surveys ofhull fouling bryozoans, genus *Watersipora,* which includes *W. subtorquata,* a species which has recently spread to Europe, having previously invaded temperate areas of Australasia and the US. A transeet of the Califomian coastline revealed cryptic-species level divergence within *W. subtorquata* and evidence of a divergent lineage which is not morphologically distinguishable from *W. subtorquata.* Inspection of global-scale range pattems (defined by COI) of the species, *W. subtorquata, W. arcuata* and *W. subovoidea* supports the view that patterns of establishment are dependent on genetic characteristics of widely transported propagules - most likely, pre-existing temperature tolerance variatíons.

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RAPID, CHIP-BASED DETECTION OF INVASIVE SPECIES IN BALLASTWATER USING CARBON NANOTUBE TECHNOLOGY

Mahon, R. Andrew Center for Aquatic Conservation, University of Notre Dame, Notre Dame, IN 46556, USA

Oral Presentation

Abstract: lnva iv e pecies have iníli ed high le vel. of envir nrn ntaJ and economic damage to the N rth American Great Lakes region with approximatel: 70% of inva iYes introduced through tran oc'ank shippino and hips' ballast water. Because treatment ystems for baila t water ha,•e •et to be implemented real-time monitoring of tb biological contents of' ballast tanks could info11n decisions about hip mo ement an<l halla ting prac tice!i, We are curr ntly developing a portable real-time genetic probe for the <let tion of targct invash·e ped in ship ballast. By co mbinino modern mol cular metbod. with micro0uidic dúp-ba ed technologie , baila t samples can pot ntíally be rapidly cr cned for multiple ta.rge rganj·m chus allowing infonned decisions about thc ri·k of in va ion to be made n route. Our work focuscs on organi m thal have either alread • invaded the Great Lake water hed or bavc been id nlifi das potentiall ' thrcatening tO the region and the goldcn mussel *(Limnopema fanunei)* the z bra mus el *(Dreissen polymorpha),* the quagga mu· ·el *(Dreissena bu9en.ris),* a predaton- cladoceran *(Comi9 eriusmaeot1cus),* the kili r : hrimp *(Dikcro9ammarus 1•i/Josus),* and th Chinese mitten rah *(Eriocheir sinensis).* In otd r t rapidl • detect thcsc p cíes in hallast " ·ate r amples we ha •e optimized ur s ' tem h · designing pede · specific PCR primer. for each anJ asymmetrically amp lifying a fragment f the yto hrome oxida e ubunit 1 (· 1) gene for detection fo ur no el mkrofluidic chip-ha ed s_ ·tem. Following amplification, our system ouple car bon nanotube. .in a dielectri Geld with mol cular g ne6 pr be that are targ ted to our specie of intcre t. The re ults of our work how that, ·an rapjdly ancl accuratcl • cle tect target invasive pecí in samples uf ·bip• ballast. Th e data support further anal *y* ·e s of the sy lem and ontfou el <levdopment a portable real-time det cti o,;- stcm thac co uld b u ed on board a ship during tran pon, prior lo di. charg ing balla t.

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LOSS OF NATIVE BLUE MUSSEL BEDS - GAIN OF ALIEN OYSTER REEFS: STATUS QUO OF SYSTEM CHANGE IN THE INTERTIDAL FLATS OF LOWER SAXONY, GERMAN W ADDEN SEA

Markert, Alexandra Research Institute Senckenberg, Wilhelrnshaven 26382, Germany Achirn Wehrrnann Research Institute Senckenberg, Wilhelrnshaven 26382, Germany Gerald Millat National Park Adrninistration Wadden Sea of Lower Saxony, Wilhelrnshaven 26382, Gerrnany

Oral Presentation

After a trernendous spatfall event following the ice winter of 1995 /96, native blue rnussel stocks *(Mytilus edulis)* in the intertidal of the Wadden Sea of Lower Saxony (Gerrnany) decreased continuously frorn 110,000 tons total wet weight in 1999 to 9,000 tons in 2005 while rnussel bed area declined frorn 3,000 to 1,000 ha. Failing recruitrnent accounts for the loss in population sustainability. The collapse of native blue rnussel beds is superirnposed by the forrnation of alien oyster reefs. First non-indigenous Pacific oyster *(Crassostrea 9i9as)* was found in 1998, invading the area by eastward larval drift frorn the Dutch Wadden Sea. Oyster larvae settle on any kind of hard substrate, which rnainly was provided by the intertidal blue rnussel beds . Distinct densities of Pacific Oysters per rn^2 were not observed befare 2004. Thereafter, an exponential increase in abundance occurred. In 2008, 107,000 tons total wet weight of the bioinvader was calculated while rnussel bed area rernained unchanged. As Pacific oysters prefer settling on conspecifics, flexible blue rnussel beds transform into rigid and stable bioconstructions (reefs) which representa new habitat type in sedirnentary tidal flats of the Wadden Sea. With the rnassive spread of the non-indigenous oyster, the subsequent loss of the habitat type blue rnussel bed and the increase in reef developrnent, blue rnussel stocks unexpectedly recovered frorn failing recruitrnent. Blue rnussels favor settling within the oyster reefs and total wet weight increased to 23,000 tons in 2008.We present data frorn 10 years ofblue rnussel rnonitoring and data for Pacific oysters frorn the first record of the bioinvasion up to 2008,including the last 6 years of oyster rnonitoring. We focus on the invasion dynarnic, the transformation of blue rnussel beds into oyster reefs and show srnall-scale distributions of oysters and blue rnussels on single sites. Besides the irnpact on blue rnussels, further prelirninary irnplications dueto thesystern change will be discussed in terrns of ecosystern engineering.

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MITOCHONDRIAL DNA IN THE BRYOZOAN MEMBRANIPORA CHESAPEAKENSIS. EVIDENCE OF A RECENT INTRODUCTION TO BOTH COASTS OF THE UNITED STATES.

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Oral Presentation

In 1995 the bryozoan *Membranipora chesapeakensis* was first described from Chesapeake Bay, Virginia. We have since documented this species for the first time in San Francisco Bay, California and on the hulls of ships in Chesapeake Bay and ships transported from San Francisco to Brownsville, Texas. CO 1 analysis of populations of *M. chesapeakensis* on ships and both coasts of the US were genetically almost identical, with < 1% sequence divergence and 8 haplotypes among all 30 colonies. The extremely low sequence diversity, existence of large colonies on ship hulls in both estuaries and time line of discovery in North American embayments suggests a recent introduction to North America. Asia is a possible source region, as the existence there, of a very similar species, *Membranipora lin9din9ensis* described in the 1980s, may be identical to *M. chesapeakensis.* Further sampling and DNA work is necessary to determine the native range and source of the introduction to US waters.

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ASSESSING THE RISK OF TRANSPORTING NON NATIVE SPECIES TO SCOTLAND VIA BIOFOULING ON VESSELS.

McCollin, Tracy and Lyndsay Brown, Marine Scotland, Marine Laboratory, Aberdeen, Scotland ABl 1 9DB, UK

Poster Presentation

A new project to assess the biofouling on vessels arriving in Scottish waters has been underway since April 2009. The project aims to obtain information regarding which species are being transported via biofouling and whether particular vessels e.g. recreational or commercial, or voyages e.g. **UK** based or international, pose a higher risk. This will be achieved by visiting dry docks to sample the hulls and other areas of vessels that are subject to reduced laminar water flow and will also use a series of in-water methods (e.g. remotely controlled cameras, divers) to record and sample biofouling on vessels. The combination of these methods will enable samples to be collected from a variety of vessels from different origins. From a marine environment perspective, preventing the introduction of non native species is of vital importance as once a species becomes established into an environment it is highly unlikely that it will ever be eradicated. This project will provide a better understanding of the risk associated with shipping vectors and will ensure that the nsks of introducing non native invasive species via this vector can be better assessed and managed, resulting in better protection for the marine environment.

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AN EVALUATION OF METHODS TO CONTROL ATLANTIC BAMBOO WORM IN THE NORTHEASTERN PACIFIC ANDA PROSPECTUS FOR LARGE-SCALE APPLICATION.

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Oral Presentation

The Adantic bamboo worm *(Clymenella torquata)* is a tube-building polychaete native to the northwestern Atlantic . While not generally known for strong interactions within its native range, invasive populations of bamboo worm in the northeastern Pacific have affected soft-sediment communities and disrupted oyster culture operations. In Puget Sound, Washington, bioturbating worms destabilize sediments, thereby indirectly increasing mortality of oysters that subside into unconsolidated mud. Recent increases in the population of bamboo worm in sorne embayments have led growers to abandon affected culture grounds entirely. In 2007, the ecology ofbamboo worm was investigated and surveys were conducted to ascertain the extent of the invasion. A field experiment tested the suitability of various physical disturbances (shell application, rototilling, hydraulic pumping, covering, and compression) as control methods by measuring effects on worm biomass, tube mass, sediment compaction and eelgrass *(Zostera* spp.) cover. Of the five treatments, rototilling was found to be the most effective in decreasing worm biomass and tube mass and increasing sediment compaction after one month. In 2008 and 2009, experimental plots were revisited to determine whether treatment effects had persisted. These data, along with laboratory investigations of burrowing speed and tube-building rates, are synthesized to assess the feasibility oflarge-scale control. We propose a control strategy that is cost-effective and considers the ecology of the organism.

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THE INVASIVE EUROPEAN GREEN CRAB, CARCINUS MEANAS, IN PLACENTIA BAY,NEWFOUNDLAND,CANADA

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Oral Presentation

In August 2007 a local fish harvester in Placentia Bay discovered a green crab that he suspected was the invasive European green crab, as described on AIS identification cards distributed throughout the province. The crab was confirmed as *Carcinus meanas* by Fisheries and Oceans (DFO) personnel. A full AIS survey was conducted for two weeks in September 07 in Placentia Bay led by DFO scientists as part of its AIS Science Monitoring Program, with collaboration from Memorial University of Newfoundland (MUN)/Ocean Sciences Centre and the Marine Institute, the provincial Department of Fisheries and Aquaculture (DFA), and fish harvesters in the effected areas. A well established multi-year class population of green crab was found in one community in northern Placentia Bay. Green crabs were detected at several other communities near the northern areas of the hay but the numbers were substantially less. Additional surveys were conducted in June and September of 2008 to determine population spread through the hay. During the survey, concern grew as the impact of the green crab invasion was shown in heavily infested areas. Destruction of entire clam, scallop and mussel beds were revealed through beach surveys and SCUBA diver transects. Impact on eelgrass habitat was of particular concern as Placentia Bay contains vital eelgrass bed habitat for juvenile commercial fish species. The impact on other crustacean species including the native rock crab, *Cancer irroratus* and the commercially important American lobster *Homarus americanus* were of increasing concern. Once the extent of the invasion was determined, a workshop (chaired by DFO Science and Policy / Economics) was held ip February 2008 with interested stakeholders to discuss mitigation strategies. The Fish Food and Allied Workers (FFAW) union took the lead in developing a pilot project to control the green crab population in Placentia Bay. In two phases, one in July- August for 12 days and then in September for 10 days, lobster fish harvesters in the most heavily impacted areas worked with DFO Science, MUN and DFA using Fukui traps to collect green crab for analysis. During this period over 25,000 pounds of green crab were caught. This represents an estimated 350,000 green crabs taken from this area. Plans for the 2009 surveys and a second population control project are underway.

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INVASIVE SPECIES PLUS POLLUTION: RECIPE FOR A SUPER INVASIVE?

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Oral Presentation

Marine ecosystems are increasingly threatened by anthropogenic stressors such as non-indigenous species and pollution. Initial evidence suggests that non-indigenous species may gain an ecological advantage in metal-polluted environments. Such an advantage depends on the evolutionary potential of these species to adapt to anthropogenic stressors. Using a laboratory based toxicity assay, we investigated the copper tolerance ofthe non-indigenous bryozoan *Watersipora subtorquata* from different source populations. Individual colonies were collected from four sites within Port Hacking, (Sydney, Australia) and their offspring exposed to a range of copper concentrations. Settlement and complete metamorphosis (recruitment) were measured as ecologically relevant endpoints. La:rval sizes were also measured for each colony. Successful recruitment was significantly reduced by the highest copper concentration of 80 Mg 1-1. While there was no difference in pollution tolerance between sites, there was large variation in the response of colony offspring within sites. Larval size differed significantly both between sites and colonies and was positively correlated with tolerance. A recruitment study in the field then investigated the settlement preferences of *W. subtorquata* in ambient and elevated copper conditions. Overall recruitment was significantly greater to the copper treatment despite greater mortality, suggesting that despite potentially higher costs larvae are actively selecting and surviving in the contaminated environment. The high level of variation in copper tolerance between colonies and recruitment preferences of larvae suggests that there is considerable potential within populations to adapt to elevated copper levels. Also, colonies that produce large larvae are more tolerant to copper suggesting that tolerance may ei.ther be a direct consequence of larger size ora pleiotropic consequence of genes that lead to larger larvae. The positive effect ofheavy metals on recruitment effectively increased the propagule pressure of this bryozoan. This effect together with increased metal tolerance will enhance the spread and establishment of this invasive species in polluted environments.

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DEVELOPMENT OF TECHNOLOGIES FOR SURVEILLANCE AND **MeNITORING** OF MARINE PESTS IN NEW ZEALAND

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Oral Presentation

In New Zealand there is a need to develop a co-ordiriated framework of technologies to aid in surveillance, compliance monitoring and identification of marine pests. This has arisen from a strategic directive for more effective surveillance and improved tools for detection, New Zealand acceding to the IMO Ballast Water Convention, and the emergence of more effective technologies for identification and sampling. Our research programme seeks to develop tools for: (i) detection of high ranking marine pests, including New Zealand unwanted organisms, (ii) improved taxonomic designation of species, and (iii) rapid identification and enumeration of viable organisms in ships' ballast water. We have designed and tested a sandwich hybridisation assay for detection of *Asterías amurensis* using a probe targeting the ITS rRNA region and have adapted a real time PCR assay for this species targeting the mtCOl gene to test for cross-reactivity against closely related New Zealand native species. A real time PCR assay is also being developed to detect the Asian clam, *Corbula amurensis,* and preliminary results will also be presented on the development of a real time PCR assay for identification and quantitation of indicator microbial species to levels defined in the IMO standard. A DNA barcode database of reference COI sequences from vouchered specimens of native crustacea, echinoderms, molluscs, polychaetes, and tunicates is being established for the molecular identification of invasive species. This has been used to identify the brown mussel *Perna perna* and the tunicate *Eudistoma elon9atum* in New Zealand waters. The pathway for implementation of the technologies will be described including levels of sampling required to meet the levels of confidence necessary for surveillance and in establishing compliance (or otherwise) to international standards.

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POLICY GAPS IN CALIFORNIA'S APPROACH TO MARINE BIOINVASIONS

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Oral Presentation

Current policies far the prevention, management, control, and eradication for marine invasions have been criticized as incomplete and insufficient. Therefore, the new California Aquatic Invasive Species Management Plan calls for an analysis of current policies regarding marine bioinvasions. After compiling a list of international, federal, and detailed state policies, we performed a gap analysis to identify which policy tools California is lacking in regard to all major vectors of marine invasions. This analysis was conducted by using a framework of policy tools, as well as performing interviews with a broad set of stakeholders. Gaps were identified in policy tools, such as prevention, management and control, and enforcement and implementation. Our final database and report identifies possible options to fill these gaps, which stem from current policies and programs in effect in other states and countries.

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SCALE DEPENDENT CONTROLS <W ('OMMI INI 1 ,. IN\'!\'di 1H I\HII I t 1t1 t\I ,\ 11• 11, 11, MARINE FOULING COMMUNITIES

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Oral Presentation

At mal! spatial cales high re id nt diversit)' ofte n results in reduced invasion success, while at larger ·patial ·cales native and invader diversity have b ee n shO\.\'Il to be positively correlated. This apparent paradox has been attributed to two difTerent mechani ms working at different spatial scales. At small scales, neighborhood int erac tion reduces establi bmc nt of new species and limits their impact (biotic resistance). At larger cale s how ever, habitat b terogeneity i often used to explain the positive correlation between inva der and native di ver ity. ln vasion of comm unities though is really a question of species coexistence. As resource heterogeneity and species diversity are both mechanisms that have consequence for coexistence, they shou1d influence communities across scales. Here we present the results of the first experiment testing the simultaneous effects of richness, species identity and habitat heterogeneity on invasibility of assembled marine sessile communities. We hypothesized that communities with low species richness and high heterogcneity wo uld be mo t ·u cep tible to invasion. We found that species richness and species identity (but no t heterogeneity) alTected in va ibilit y at small cales. However, when we scaled up our communities, mor e het crogen ou o mmun itie bad increa ed invader richness and percent cover. We also found a *Co9mactis cal!fornica,* decreasing pcrccn t cover of invaders with increasing hetero geneity. In addition, beterogcncity affi et invader impact at ver small scales. Differences in heterogeneity at these smaller than neighborhood cales may exp lain th high r relation we see between exotic and native diversity at larger cales. We propose a ne, framework for tlunk.ing about invasibility of communities across scales where species identity, species richness and habitat heterogeneity interact to promote or inhibit coexistence and thus invasion in communities.

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STRATEGIES FOR PCR-BASED DETECTION AND QUANTIFICATION OF PLANKTONIC LARVAE

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Oral Presentation

The detection of species-specific DNA sequences in planktonic larvae can be accomplished by any of several technologies that rely on the specificity of DNA hybridization, However, there are many considerations that should be weighed in the design of a strategy for the detection of the larvae of non-native species. Generally, there will be tradeoffs between cost, sensitivity, and accuracy, and sorne approaches will require more initial development than others. Beyond simple detection, DNA-based quantification oflarval abundance is also possible although challenging. We have explored the use of different approaches to sample preparation (single specimens, bulk samples), choice oftarget sequence (nuclear repetitive, nuclear single-copy, mitochondrial), methods of detection (gel electrophoresis, fluorescent probes) and quantification (competitive PCR, real-time PCR) with the larvae ofboth native and non-native species off the coasts of Louisiana, California, and Caribbean Panama. We will present results that demonstrate: 1) it is possible to detect larvae with considerable accuracy and sensitivity; 2) sorne species that have not been reported from an area can be detected as larvae; and 3) mixed success for quantification oflarval abundance with identification of key areas in need of improvement. W e will also present initial results of a survey of plankton from San Francisco Bay and adjacent areas of the Pacific coast for several marine invasive species.

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AN EVALUATION OF VIABILITY ASSAYS USING A CONTINUOUS IMAGING PARTICLE ANALYZER (FLOWCAM®)

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Oral Presentation

A major source of invasive species in aquatic environments is ballast water discharge from vessels as they travel from port to port. A Ballast Water Convention has been adopted by the International Maritime Organization that will require vessels to treat discharged ballast water limiting the number of viable organisms from entering the environment. The FlowCAM®, an imaging flow cytometer, is an instrument used for rapid plankton detection and analysis, with the ability to detect auto-fluorescence (chlorophyll) or stain-induced-fluorescence in organisms. The fluorescence is used as a "trigger" for a camera to capture images of target organisms within a sample. The FlowCAM adds a unique capability to the ballast water monitoring process by using different stains to determine the viability of organisms in ballast water. Data such as concentration calculations, measuring the minimum diameter of organisms, and size distribution, is easily determined by the instrument. Compared to traditional microscopic methods which are laborious and plagued by operator error, the value of FlowCAM lies in the immediate feedback the user receives with regard to viability and data analysis. We present results of different viability assays using the FlowCAM, using bcith fluorescent and visual stains, in order to determine how effective these assays are at detecting viable organisms in ballast water.

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NEW METHOD TO DETECT ANO IDENTIFY INVASIVE BIVALVES USING A CONTINUOUS IMAGING PARTICLE ANALYZER (FLOWCAM®)

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Oral Presentation

Monitoring water systems for invasive Zebra and Quagga Mussels is an extremely important yet daunting task for the water quality professional. Interestingly, the vel gers of these taxa have very unique optical properties differentiating them from other organisms. The shells of the Zebra and Quagga Mussels are calcerous, and when viewed with a cross-polarized light source, reflect the Llght from the calcite, emitting a unique pattern commonly referred to as the 'Maltese Cross' (a phenomena called Birefringence), even when viewed as veligers in their planktonic state The imaging particle analyzer -- FlowCAM - has been in use since 2000 by microbiologists to study plankton in marine and freshwater systems. The instrument utilizes a combination of light sources and filters (532 nm laser - or optional 488 nm - Flash LED, two Ernission Filters) to detect and image microscopic organisms and particles in a fluid stream. With an understanding of the natural optical properties of these organisms, Fluid Imaging Technologies, Inc., manufacturer of the FlowCAM, has added two new assemblies that allow the instrument to detect the presence of the birefringence of mussel veligers. Once detected, organisms possessing these unique characteristics are imaged for purposes of identification and enumeration. An overview of the technology will be given, along with data from enumeration studies, as well as data from natural samples.

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TESTING CHEMICAL TRACERS AND THE BEAM AS A METHOD TO VERIFY BALLAST WATER EXCHANGE.

Monaca Noble, Jennifer Boehme, Kathleen Murphy, Darrick Sparks, Christopher Brown, and Gregory Ruiz, Smithsonian Environmental Research Center

Oral Presentation

Ship's ballast water is an important vector for the transfer of marine pecie throughout the worl<l and various management efforts are advancing to treat baila t water and thereb ı reduce th ri k of as ociated invasions. In the U.S., commercial ships arri ving from over cas and across sorne coa twi e (domestic) routes are required to treat their ballast water befare d' charge. While technologies are still being developed, ballast water exchange (BWE) is the only treatment mcthod tbat is approved and available far routine use. During BWE, the ship replaces its port or coastal ballast water with water from the open ocean. This process removes mo·t of the coastal organisms, thereby reducing the likelihood that non-native pecie can estab lish whe n tbe ballast water is relea ed in a coastal port. One critica! gap in BWE far re ource managers i • in the aYaHa b ili ty of r bust methods to verify quickly (in real time) whether exchange has o curr e<l and \ a pe1·fonnecl prop rl '. We ḥa e been testing the use of chemical constituents of sea water to djstingw h port and open-oc an sour ce . Extensive analyzes demonstrate that chromophoric dis ol ved o rganic matter (CDOM) is hig hly succe ful at discriminating port from open-ocean water, providing the potential to verif • BWE. T o under tand the potential application of BWE verification in the fiel<l, we (a) co mpared concen tr atio n · of CDOM in bafüst tanks to expected concentrations, based upon reported source and regional CDOM data, and b) \'alu ated thc efe et f tank access loca ti n (man ho le vs. sounding pipe), ship and tank type, and exchancre tvp on concen tra tion . amples \ ere collecte d h enfarcement officers from multiple agencies. Each agency u cd the sarne equipment ancl ampling protocol to sample mult iple" es el. and ve se l t p . One tank \\, s am pled p r hip at GYO lo cation · (manh <>le and sounding pipe). Our result in dica te that ome sbip. bada high concentration of CDOM, cle"5pite report d BWE S\1gge ting either th exchangc did not occ ur or was it wa incfficien t. There was also a sign ifk ant dilTerence between ample ollec tecl from the ounding pipe ve rsu the manhol access p in t. m samples collectecl through the soundi ng pipe had hiohl e le vatecl DO M, <.:o m parecl to sam plcs <.:o ll ·t d through the manhole or t he . ame tank. Overa.11, our r es ul ts sugg st DOM concen t1-ati n pro idu; a uscl'ul measure far B E verifi cation and some tank sam ple I cations uld result in a fal e positi rcsult.

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HYBRID ASSIMILATION IN SPARTINA: RE-EVALUATING CONSERVATION GOALS

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Poster Presentation

Hybridization between native and introduced species of Spartina (cordgrass) have significantly altered wetland habitats and created challenges for conservation in locations around the world. Since the hybridization between introduced smooth cordgrass *(Spartina alterniflora)* and native Pacific cordgrass (5. *foliosa)* was first documented in the San Francisco Bay, California, USA, in the early 1990s, we have witnessed the population explosion of invasive hybrids and the development of a genetically variable hybrid swarm. The California Coastal Conservancy's San Francisco Estuary lnvasive Spartina Project (ISP) has systematically removed plants with obvious hybrid morphology or ecology as they work to eradicate invasive Spartina from the San Francisco Estuary. In the course of monitoring eradication efforts, we use genetic testing to determine the parentage of hundreds of cordgrass samples each year. The results of these genetic tests show that highly backcrossed hybrid plants, with no obvious morphological characteristics to distinguish them from natives, are "hiding" in the marshes of the Bay. Through the process of adaptive management, the ISP and the conservation community must now evaluate the extent of these "cryptic hybrids" and set realistic conservation goals based on the current and projected extent and consequences of hybrid assimilation.

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DYNAMICS AND ROLES OF ALIEN SPl:Cll:S IN TI lli ('I IAN<;tN<; ENVIRONMENT OFTHE BALTIC Sl:A

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Oral Presentation

Altogether over one hundred alien species have been recorded in the Baltic Sea. They originate from different areas around the World and have been invaded the Baltic during various times. During the recent decades, several new invasions were detected and several already existing alien species have increased in population ize and range distribut io n. In thi st ud y, we inve tigated spatio-temporal variability of clcct d ali n specie repre en ting düTerent trophk leve ! (zoop lank ton , macrozoohentho , fi h) and ecológical function . Firstly, we idcntifi d similari ties and d.ifference in patial d ·namks of these species over time (annual and decadal scale), incl. in relation to their native ilistribution area, and tried to identi, th factors responsible far the observed patterns. Further, dynamks of importance of these alien species in biotic communities was studied enabling so quantification of their role and impact in the system. Our final analysis aimed at identifying whether the observed invasion success is dueto climate induced change in abiotic environment or caused by complex alterations in abiotic and biotic components of the ecosystem and in this way corresponded to general regime shifts of the Baltic Sea .

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RISKY BUSINESS: ASKING LIFE'S PERSISTENT QUESTION, CAN WE PREDICT THE LIKELIHOOD OF MARINE SPECIES INVASIONS?

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Oral Pres enta tion

A persistent question in marine bioinvasions science is can we predict the likelihood of species arrival, survival, establishment , and spread? The genetic algorithm for rule-set production (GARP) has ser ved as a model for Canadian risk assessment approaches and has been applied to a number of marine species, including ascidians, carp, and decapods . For the northwest Atlantic , several species present in Europe, one of our majar trading partners, have yet to show up in the U.S. This approach requires input from a number of experts to develop high, medium, and low risk assessments and levels of certainty . In this study, we used a modified and simplified approach as a first approximation to assess the risk of arrival and identify potentially favorable geographic area for six marine species. The species examined in this survey include two algal species *Undaria pinnatiflda* and *Saraassum muticum,* a gastropod *Rapana venosa,* a barnacle *Austrominius modestus,* a crab *Hemiarapsus takanoi,* anda sea squirt *Corella eumyota.* Of these *R. venosa* has invaded the Chesapeake, but the other species have not yet been reported as present . The approach used includes (a) risk from the shipping vector, (b) physiology of organisms, and (c) temperature and salinity data. We used the National Ballast Information System reports to determine the likelihood of the species in the ballast and shipping pathway. Information on survival oflarvae and/ or adults and where available, reproductive requirements were gathered from published literature and reports. Datasets from the Northwest Atlantic coastal buoys locat e d in shallow areas with year-round salinity and temperature data indicate length oftime at maximum and mínimum tem peratur e and salinity for thes e areas. The U.S . environmental data were compared to environmental data from the species native ranges and / or invaded areas. Results indicate that temperatu re appears to limit invasions, but with rising temperatures predicted from climate change studies introductions are increasingl y likely.

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FROM MEADOWS TO MUD: INVASIVE FISH DRIVli A l'l IASI 1111·1 IN I l..\ WMl N SEAGRASS HABITATS

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Oral Presentation

Tüapüne fishe (ti lapia) were introduced globally frorn the.ir nath ·e ranges in Africa becau e their bigh fecw1dity, wide aBnity and temperature tolerances, and omni ory made them well-suited for aquaculture, recreational fish:ing and biocontrol of aquatic insects and weeds. Unfortunately, tb.i ame uite of attribute s has predisposed tilapia to be invasive. Surveys in coa ·tal v etland across the Hawaiian íslands re vea ! d that the euryhaline seagrass *Ruppia marítima* was scarce . Th:is wa un xpected since there is cxtensi e eagra ·s habitat in wetlands set aside as waterbird sanctuaries throughout the arch ipelago. ln contrast, two euryhaline tilapia species/h brids, introduced over 40 yea: 1 ago, bad invaded many of tbe ,vaterbird san tuarie pre ent,l devoid of agras . I-lere we report empirical work to upport the h •pothe i tbat bigh den ilies of tilapia cata trophically eBminatcd the seagra s from the wetland where tl1e fish im·aded. The tilapia con um d the vegetative canopy completely resulting in a pha e h.ift ú-om a macrophyte-dominated tem of" eagras and green macroalgae to a ·ol ely mkrophytobenth:i (microalgae) community. The capacity for tilapia to oppo1tunisticall hift their diet to one primaril • composed of microphytobenthos is a o·ait of parti uJar sionificance in this jnvasion proc s. Es entially, tilap ia bave the ability to maintain a lower-tro phic level sy tem b virtllc of their ver ati1c diet, allowing th ílsh to 0ouri b and mainta.in a elf-·u taining population a a primary consumer in the inva<led coastal pond . Here we report one of the flrst case of an aquatic in\'asive p cies driving the complete loss of a specie· of concern fo coa. taJ wetland . This i · al o the flr t report of inva ¡.,.e 6sh negativel impacting a seagras a well a the ñrst experimental evidcnce of an introduc d fi h n gativ ly af cting biodiversity in Hawaiian coastal habitats.

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l:COLOGY AND RESTORATION OF SPARTINA DENSIFLORA-DOMINATED SALT MARSHES ON THE NOR TH COAST OF CALIFORNIA.

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Oral Presentation

Invasive dense-flowered cordgrass *(Spartina densiflora)* has hada major impact on Humboldt Bay, California, where it has come to dominate the salt marsh since its introduction in the 1800s. Although acknowledged as a serious ecological threat since the 1980s, managers have been unable to initiate meaningful control because the only method presumed to be effective for a rhizomatous perennial - chernical control - has been highly controversia! and vociferously opposed by the community. The US Fish and Wildlife Service (Humboldt Bay National Wildlife Refuge) with funding from the State Coastal Conservancy demonstrated the feasibility of using mechanical methods (weedeaters) to eradicate *S. densiflora* from experimental plots on a salt marsh island site at Humboldt Bay National Wildlife Refuge overa two year period. Following this small scale success, and with joint funding from the U .S. Fish and Wildlife Service and the State Coastal Conservancy, an 8 .1 ha control project was undertaken on a mainland salt marsh at the refuge. By the end of the second year, virtually all original *Spartina* was eradicated. The marsh remains vulnerable to reinvasion from tidally dispersed seeds and annual maintenance will be needed unless regional eradication is accomplished. During the same period, native species recovery progressed substantially in all but a few low-elevation anoxic areas. Revegetation with native plants has moved even these areas successfully along the restoration trajectory. Based on the success of the project, a two-year research grant was awarded to the Service from the State Coastal Conservancy to determine whether a persistent seedbank is present, to refine monitoring techniques (including tirning of treatments), and to quantify impacts of mechanical restoration on rare plants, tidal creek geometry and invertebrate communities (the latter is being carried out by a Humboldt State University graduate student). The presentation will summarize what is known about the ecology of *Spartina densiflora* in Humboldt Bay, will present quantitative results of mechanical restoration techniques, revegetation, and results to date of those portions of the research program being carried out by refuge staff.

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TAXONOMIC UNCERTAINTY AND CRYPTIC DIVERSITY IN AMPITHOE **VALI•A** AND JASSA MARMORATA, TWO BIOFOULING AMPHIPOD INVADERS

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Oral Presentation

The amphipods *Ampithoe valida* Smith 1873 and *Jassa marmorata* Holmes 1903 are biofouling tube-builders with putative native ranges on the Atlantic coast of North America. These two were first found as invaders to San Francisco Bay, but are now found in a variety oflocations along the Pacific North American coast. Like many amphipods, morphological identification of these species is very difficult without the proper taxonomic expertise and mature male specimens. Specimens of *A. valida* and *J. marmorata* can be confused with other *Ampithoe* and *Jassa* species native to the Pacific coast. With the positive morphological identification of these two being unreliable, we chose to investigate the genetic diversity of these two taxa for DNA-sequence based means of species determination. Results for *Jassa* showed that juveniles are easily confused between *J. marmorata, J. slatteryi,* and *J. staduei,* but that large diagnostic genetic distances exist between *Jassa* species. Results for *A. valida* showed three distinct clades with Pacific North American populations with sorne having limited distributions. Of the three clades of invasive *A. valida,* only one clade srowed strong genetic similarity to *A. valida* populations from the Atlantic North American coast. These results call into question the number of invasions on the Pacific coast and whether cryptic diversity further muddles our ability to identify invasive amphipod species.

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BIOGEOGRAPHIC VARIATION IN ABUNDANCE, HABITATUSE, ANO BEHAVIOR OF THE EUROPEAN GREEN CRAB, CARCINUS MAENAS

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Oral Presentation

Many studies of invasive species seek to quantify the degree to which a given area is invaded by a suite of different invaders. In contrast, the focus of this study is to quantify variation in invasion of a single invader, the European green crab, *Carcinus maenas,* across a broad biogeographic scale. Invader success is often attributed to lower pressure from competitors and predators in the invaded range. Furthermore, species-poor or highly disturbed habitats are often more invaded. Dueto close proximity to anthropogenic activity estuaries are often highly disturbed and may offer less biotic resistance to invasion than adjacent open coast. In this study, we tested two hypotheses: 1) Do individual and population level indicators of invasion success such as abundance, size, and behavior indicate more success in invaded than native ranges? 2) Are green crabs more successful in estuaries than on the open coast? The objective of this study is to measure parameters describing invasive green crab populations and to characterize variation in these indicators in the native and invaded ranges. We sampled the native range of C. *maenas,* the European Atlantic coast, as well as the US Atlantic Coast invaded approximately 200 years ago, and the US Pacific Coast invaded approximately 20 years ago. All coasts were sampled in 2006 and 2007. On each coast, we measured individual traits (e.g. average and maximum carapace width, intra- and interspecific aggression) in addition to population traits (e.g . relative abundance, size distribution and habitat use (open coast vs. estuaries), and the ratio of native to invasive crabs. Our results include four key findings regarding biogeographic variation in C. *maenas:* 1) Average carapace width is significantly greater on the US Pacific Coast than on the US and European Atlantic Coasts; 2) Intraspecific aggression is lower on the US Atlantic Coast than in the native range or on the recently invaded US Pacific Coast; 3) Abundance is significantly lower on the US Pacific coast than on the European and US Atlantic coasts; 4) Habitat use is limited to estuaries on the US Pacific coast but not on the European and US Atlantic coasts. In order for community ecologists and coastal managers to better prio_ritize efforts of prevention, management, or eradication of invasive species, there is a strong need for research addressing large scale biogeographic patterns of spatial variation in abundance, habitat use, and behavior of invaders.

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REPRODUCTIVE PHENOLOGY OF THE INTRODUCED KELP UNDARIA PINNATIFIDA (PHAEOPHYCEAE, LAMINARIALES) IN PORT PHILLIP BAY (VICTORIA, AUSTRALIA) COMPARED WITH TASMANIA.

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Oral Presentation

A thorough understanding of the reproductive phenology of introduced species is crucial for effective management and control. *Undaria pinnatifida* is an invasive macroalga from the Northwest Pacific which has been recently introduced into three countries in the Southern Hemisphere: Australia, New Zealand and Argentina. Reproductive phenological studies in Port Phillip Bay, Australia, were undertaken and compared with other populations in the Southern Hemisphere, especially with those from Tasmania which are suspected to be very different. The growth season began earlier in Port Phillip Bay than in Tasmanian populations, and abundance was higher. Growth rates were lower in Port Phillip Bay, but this might be due to the different morphology of both populations. The maximum zoospore release of *U. pinnatiflda* in Port Phillip Bay was 12.1 x 105 spores cm-2 h-1 which is 20 times the maximum obtained in Tasmania (0.6 x 105 spores cm-2 h-1). For most of the growth season, zoospore release ranged between 2-3 x 105 spores cm-2 h-1, three to five times more than in Tasmania. Port Phillip Bay populations of this introduced kelp are more abundant and primarily present in harbours and marinas on artificial structures, while Tasmanian populations are less dense and generally located in natural habitats. These characteristics will make Port Phillip Bay populations more risky with regard to potential spread than other locations. *Undaria pinnatiflda* is currently restricted to Port Phillip Bay in continental Australia, but a precautionary approach should be undertaken in order to avoid further spread.

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ESTIMATING PROPAGULE SUPPLY BY SHIPS

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Oral Presentation

Relatively few non-native marine species are known from Alaska and other high-latitude regions around the world. This may result from differences in propagule supply or susceptibility to invasion compared to more temperate regions. To better understand ship-mediated propagule supply, we have begun to characterize the potential magnitude of species transfers associated with ballast water of ships arriving to Alaska, focusing on tankers. In a previous study (1997-1999), we conducted an analysis ofballast water volume and associated biota for oil tankers (n> 180) arriving to Valdez from the western United States. A more recent study (2007-2008) provides parallel measures for LNG tankers (n=9) arriving to Nikiski from Japan.
Together, these data indicate that large per-ship inocula of plankton have occurred in Alaska' s coastal waters, including a diverse collection of non-native taxa from foreign and domestic source ports. lnterestingly, two of the dominant source ports for domestic ballast water are in California and are themselves heavily invaded. From analysis of these vessels alone, we surmise that (a) the recent ship-mediated supply of non-native species to Alaska is relatively high and (b) the limited number of invasions to date reflect either a lag-time in invasion (or detection) or low susceptibility to invasion. The recent northward spread into Alaska of severa! non-native marine species, combined with the apparent thermal tolerance for other species, suggest Alaska is indeed susceptible to invasion. We hypothesize that the location of these particular arrival ports, including especially the surrounding environmental conditions and habitats, may have helped limit the current rate of colonization to date.

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MARINE BIOINVASION STUDIES IN THE NORTH-WESTERN PART 01" TI 11 : SI/\< ll JAPAN

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Oral Presentation

A working group has been established in May 2007 to coordinate studies on the invasive species in til!' l:,r eastern part of Russia. The group includes members of the Institute of Marine Biology, Russian A(',1cl1·111y 111' Sciences, and the Sea Protection Institute, both located in Vladivostok, Primorsky Region. In l't>t>jH'l'o1ti1111 with the Sea Ports of Vladivostok, major vec tors of ship transportations in the Sea of Japan havt· l1t •1· 11 determined anda strategy of a complex investigations has been developed. Samples of fouli11g ,111cl l,.dl.1•,t water have been regularly collected since June 2007. First results of this investigation arl' s1111111111.11 i, , ,. .111.J presented, including a complete list of non-indigenous species in the north-western part 111" llw S,·,1 il 1·'1 „11,

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PER CAPITA INVASION PROBABILITIES: A LINEAR MODEL TO PREDICT RATES OF INVASION VIA BALLAST WATER

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Oral Presentation

Ballast water discharges are a majar source of species introductions into marine, estuarine, and freshwater ecosystems. Far example, in the San Francisco Estuary, dubbed the "most invaded estuary in the world", it is estimated to account far 38-76% óf the aquatic invaders. To predict the potential rate of invasion from ballast water, we developed a linear invasion model based on historie invasion rates far the San Francisco Estuary and Great Lakes. The per capita invasion probability was calculated by dividing the number of ballast water invaders by the total number of organisms discharged via ballast water, which was estimated from total volume of ballast discharged times the mean ballast water concentration of organisms. The resulting per capita invasion probability represents the likelihood that a single discharged organism becomes established. In these calculations, we used a mean ballast water concentration of 4640/m3 far organisms >50 microns. Based on data from the National Ballast Information Clearinghouse, an average of 819,364 metric tons per year ofballast water from fareign ports was discharged into the San Francisco Estuary from 2004-2008. Between 1991- 1995 it is estimated that the invasion rate from ballast water in the San Francisco Estuary was 1.6-3.2 species per year. Assuming an underestimate of 100% dueto unknown, unidentified and unclassified species, invasion rates were adjusted to 6.4 species per year. Assuming a linear <lose-response relationship, the per capita invasion probability far San Francisco Estuary is 1.68 x 10-9. Far the Great Lakes, the National Biological Invasion Shipping Study recorded that the total annual fareign ballast water discharged in 1991 was 1,395,461 metric tons. The invasion rate was estimated at 2 species per year, yielding a per capita invasion probability far the Great Lakes of 3. 09 x 10-10. These two well studied systems provide a first approximation of per capita invasion probabilities that can be used to estimate the probability ofinvasion from either a single ship's discharge, or the total volume ofballast discharged into a system. While these numbers will vary linearly along a continuum of ballast discharge values, organism concentrations, and invasions rates far individual places, we suggest that these per capita innsion probabilities far the San Francisco Estuary and the Great Lakes are viable surrogate values far other less studied estuarine and freshwater areas.

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ECOLOGICAL INTERACTIONS IN MARINE BIOINVASIONS: A GLOBAL PERSPECTIVE

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Oral Presentation

In the process of establishment and integration of an invasive species in a new region the invader can interact with native and other invasive speéies in a variety of ways including competition, predation, ami facilitation (for example through ecosystem engineering). Sorne of these interactions can have communil y or even ecosystem level effects. In a recent book on marine bioinvasions, these interactions were revicw1·d by several authors on a global scale. The results indicate that (1) there are still relatively few studies that quantitatively evaluate the strength of native-invasive or invasive-invasive interactions in the marine environment but the number of studies is growing; (2) there is a strong bias towards studies of severa! taxonomic groups, among them mollusks; (3) sorne interactions are very strong and, although thcre ,11·1· 1111 known global extinctions of a marine species dueto invasions, localized extinctions can occur. With n·g,11 ti to predation, the most studied taxonomic group of invasive predators is pelagic and coastal zoopla11kto 11 1 while the most-studied invasive prey are mollusks. It appears that (1) invasive zooplankton can hav1• 111111"', ecosystem-level, effects on their environment, (2) highly selective predators can potentially be wry effective in eliminating invaders, and (3) sorne invasive predators have the capacity to change tlw environment to facilitate further invasions. In a specific example, we will show that an invasiw l11dnp,111111 mussel, *Brachidontes pharaonis,* is distributed in a mosaic pattern along the Israelí Mediterrancan **1·0,1NI** ,111ol will explore the possible mechanisms for this mosaic distribution. The invader is replacing tlw s111o1ll,·1 native mussel in habitats where mussel beds previously existed (beachrocks) and is taking ov1·r 111·w lt,,lilt.11• where mussel beds never existed (rocky vermetid platforms) in sorne locations but not otlwrs. **W1·** \\ 111 present data that is now being collected on predation intensity, larval recruitment and thc los ni,·, **m\·•frt11** engineers (vermetids) as potential processes that shape this intriguing distribution.

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ESTABLISHMENT AND DISPERSAL OF INVASIVE ASCIDIANS ON URBAN STRUCTURES

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Oral Presentation

One of the largest human induced alterations along coastal areas is the establishment of urban structures such as coastal defences, harbours and marinas. Aside from seriously altering the dynamics of marine ecosystems, these structures can facilitate the establishment and spread of invasive specic , acting a stepping stones for organisms with restricted dispersa] capanilities and increa ing tbe connectivity bctv een remote hard bottom habitats separated by extensive soft bottom areas. However, little is known about wh invasive species establish and proliferate so successfull · on urban marin tructures, and what the rol of these structures is in the large scale dispersal of these species. We carried out a study aimed at analyzing the effects of urban marine structures in the establishment and spread of invasive tunicates, which are known to have considerable impacts on human activities. The study was done along the coast of the North Adriatic Sea. This region is amongst the most urbanized marine areas in the world, and coastal-defence structures which run almost uninterrupted for hundreds of lcilometres have promoted the expansion of sorne introduced species. We carried out an extensive field sampling at 15 sites along ca. 400 km of coastline to asses the distribution and community composition of ascidian species. The abundance of these species and other dominant space occupiers was recorded directly in the field, while several specimens were also collected to be identified to species level after a detailed taxonomic examination. Through comparisons between urban structures and natural reefs we tested whether assemblages of tunicates on urban structures include a greater proportion of invasive species than those on natural reefs. A greater abundance of invasive species has indeed been reported on a variety of artificial structures compared to natural reefs; however, little is known about the extent to which these patterns can be generalized. We finally examined the relationships between assemblages on urban structures that were built or maintained at different time periods and possible source populations (sampled in nearby harbours and marinas), in arder to get insights into the modalities by which these organisms reach urban structures. This information is fundamental to develop models aimed at predicting the rates and pathways of dispersal of invasive species that can result due to the proliferation of urban structures along large stretches of coastline

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MARINE INTRODUCTIONS IN RELATIVELY UNEXPLORED PARTS OF TI-IE WORLD: WHY DO WE STRUGGLE SO MUCH TO DETECT THEM?

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Oral Presentation

Over the past 50 years, Europe, North America, and Australia have dorninated the Üterature in terms of reporting introduced species. This can be attributed to their extensive historical records, monitoring programs and generally more concentrated presence of specialists. However even in these areas, the check list of introduced species is not always adequately updated and large numbers of invasions are missed every year. The situation is thus even more worrying in regions where the state of knowledge of the marine biota still remains relatively poor. One majar challenge is the state of systematics and taxonomy where there are often too few orno taxonornists available to make authoritative identifications. In parallel, modern interpretations of taxa are changing and this impacts species identification. One species may have many synonyms, which are constantly evolving over time. The result is a taxon may be redescribed around the world under many names yet later be identified as one species. In other cases a cosmopolitan species with many purported synonyms may be found to be several species. There is a need to combine taxonomic work, review of both historical and more recent records, and new sampling surveys across all marine habitats in a region to reveal the presence of previous misidentified, overlooked, new or potential introductions. In a relatively unexplored region, namely South Africa, the number of documented marine introduced species has increased from 1O to over 100 in the last three year period, with most of these representing species introduced long ago. In addition, the current list includes about 50 cryptogenic species. Considering that South Africa has experienced uninterrupted transoceanic shipping since the 15th century, the few taxonomic monographs developed throughout the 20th century on the marine fauna of South Africa did not recognize many of these species as introductions. This is despite the fact that most of these introductions were well-known European species with disjunct distributions. This case highlights why regions where studies into invasive biology are in their infancy, consistently report initial low incidcnccs of marine introductions. When these regions are eventually studied in depth, the number of recognízcd introductions quickly increases. Therefore, international projects like the one presented here can rapiclly assist_in identifying the true pervasiveness of marine introductions in many unexplored regions of thc world

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INTRODUCED HABITAT ENGINEER FACILITATES ITSELF AND NEGATIVELY AFFECTS A CO-OCCURRING NON-NATIVE CLAM

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Oral Presentation

Dwarf eelgrass (duckgrass; *Zostera Japonica)* and Manila clams *(Ruditapes philippinarum)* are two introduced species that co-occur on intertidal flats of the northeast Pacific. While the clams are economically valuable, Z. japonica is often considered a "weed" that interferes with aquaculture. However, interactions between the two species have not been scientifically tested. Through factorial manipulation of clam and eelgrass density, we examined intra- and interspecific effects on performance, as well as modification of the physical environment (water flow, water chemistry). Three clam densities (O, 250, 500 adult clams per 2x2 m plots) were established as split plots within three eelgrass treatments (mechanical removal of eelgrass via harrowing, removal of eelgrass by hand in 10x10 m plots, no removal of eelgrass). The experiment was carried out ata tidal elevation of ~+1 m MLLW from June to September, 2007, overlapping the summer season of peak productivity. Based on dissolution blocks, the presence of eelgrass reduced water flow by 40% and was also observed to retain water at low tide, which may explain why eelgrass actually grew faster in the presence of conspecifics (positive feedback). Harrowed areas contained high densities of small clams, suggesting that eelgrass impedes clam recruitment. Although shell growth of small clams was not affected by any treatment, clam condition improved when eelgrass was removed. In contrast, clams appeared to have weak effects on measured responses even at aquaculture densities: across clam density treatments, there were no differences in nutrients within the sediment, eelgrass growth, or clam growth. These results illustrate that large-scale removal of an invasive eelgrass concurrently removes a positive feedback and can alleviate the impact of this invasive species on the aquaculture sector.

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LATITUDINAL GRADIENT IN NON-NATIVE SPECIES RICI INl:SS **Al.**< >N<i **Wl·.STHtN** NORTH AMERICA: A RESULT OF PROPAGULE SUPPLY7

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Oral Presentation

Most marine invasions are reported from coastal bays and estuaries in temperate latitudes, with relatively few non-native species known from high latitudes or the tropics. This is perhaps best illustrated along western North America, where non-native species richness (NNSR) varies two orders ofmagnitude among estuaries and exhibits a steep decline with increasing latitude from California to Alaska. To test the effect habitat and search effort, we conducted standardized surveys of sessile invertebrates in twelve bays, ranging from 32 to 61 degrees N latitude. For this subset of taxa, NNSR declined as a linear function of increasing latitude (r2=0.90). Thus, both literature and field-based measures support a strong latitudinal gradient in NNSR. Various factors may cause the observed spatial variation, including d.ifferences in propagule supply and susceptibility to invasion, but their relative contributions remain largely unexplored. We explored the relationship between NNSR and propagule supply, focusing specifically on shipping as a supply mechanism. Commercial shipping can transport marine organisms on the hulls and in ballast water. We estimated how much of the observed variation in NNSR among estuaries can be explained by differences in number of ship arrivals, wetted (underwater) surface area, and ballast water discharge volume, as coarse proxies for ship-mediated propagule supply. Historically, a strong difference existed in the magnitude of ship-mediated supply across latitudes, such that propagule supply was relatively low in Alaska compared to California, corresponding to similar spatial pattem for NNSR. Moreover, it appears that many non-native species now resident in North America may be able to tolerate environmental conditions in Alaska, and sorne of these species are spreading northward. Together, these data suggest low propagule supply may have historically limited invasions in Alaska. We predict that risk of invasion is now increasing for Alaskan waters, as a result of increasing propagule supply, and this may be further enhanced by expected shifting thermal regime due to climate change.

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WHAT THE HULL IS GOING ON: AN ANALYSIS OF THE FOULING-RELAT PRACTICES OF COMMERCIAL VESSELS IN CALIFORNIA

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Oral Presentation

Fouling of aquatic organisms to the submerged areas of vessels can be a majar vector far the transfer nonind.igenous species (NIS) both locally and globally. Introduction of NIS through vessel fouling can as organisms spawn, fall off, orare physically removed from the underwater areas of a vessel. Many worldwide have suggested that the number of NIS introductions through vessel fouling may be equal greater than, introductions via ballast water. Although vessel fouling can be a significant contributo.- transfer of NIS worldwide, it is difficult to assess the risk of NIS introduction through this vector bec the limited amount of information on vessel practices that ínfluence fouling accumulation. Very few substantive studies have been conducted world,vide, especially in the Northern Hemisphere, evaluati fouling-related practices and how they can influence the extent of vessel fouling. In an attempt to fill information gap, the California State Lands Commission (Commission) has developed a Hull Husban Reporting Form that all vessels operating in California must submit on an annual basis, as of January 2008. This reporting form is a ten-question survey aimed at gathering information related to practic are likely to influence fouling extent on the submerged areas of vess els. These include hull husbandr practices, such as type and age of antifouling coating and length of time since the last dry doclcing or i water cleaning, as well as certain voyage characteristics, such as traveling speeds and port residency t A complete look at these fouling-related practices far all Yessels operating in California during 2008 presented and discussed, as well as potential implications far vessel fouling extent and NIS introducti risk. A preliminary view of the data thus far indicates that 98.8% of ali vessels operating in Californi been removed from the water for hull cleaning and treatment with an antifouling coating within the five years, and 80.1% of those vessels have used an antifouling coating containing at least one biocide information gathered from this form will provide detailed insight into characteristics thought to influ vessel fouling and will be used in conjunction with fouling-related research the Commission is curren funding to guide the development of regulations governing the management of fouling on vessels ope in California.

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CITIZEN MONITORING FOR THE EUROPEAN GREEN CRAB IN ALASKA

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Oral Presentation

Alaska, with approximately 44,000 miles of coastline, asparse human population, and extremely valuable seafood and coastal resources, is at risk for a possible invasion of the European green crab. Regulators, scientists, educators and citizens have come together to leverage funding and resources to initiate, maintain, and expand European green crab monitoring in Alaska in the hopes of tapping into opportunities to support prevention, rapid response, eradication and/ or control of this species befare it becomes established. Successful partnerships have developed between government agencies and other stakeholders in recent years. These partnerships have enhanced monitoring efforts and initiated new monitoring, research and educational efforts.

There is a common myth that Alaska is too cold or isolated far harmful invasive species to establish themselves. However, with climate change impacting Alaska and the fact that Alaska supports significant air and water trade routes, it is likely only a matter of time befare an invasive species arrives and spreads in Alaskan waters. Research perfarmed by the Smithsonian Environmental Research Center, indicates that the European Green crab could easily establish itself in coastal waters off Alaska. The European green crab, although not faund in Alaska yet, has successfully migrated up the west coast of the United States into Canada since it was first detected in San Francisco Bay in 1989. Through the monitoring efforts of a diverse array of participants, from school children to Native Tribes to govemment scientist, members of Alaska's coastal communities are providing information and tools to fight complacency when it comes to aquatic invasive species.

In this presentation, we will presenta successful model far cooperation amongst diverse groups with the same goal - protecting the natural resources and marine environments from harmful invasive species.

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EVALUATION OF A HABITAT SUITABILITY MODEL FOR THE INVASIVE EUROPEAN GREEN CRAB (CARCINUS MEANUS) USING SPECIES OCCURRENCE DATA FROM WESTERN VANCOUVER ISLAND, BRITISH COLUMBIA

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Poster Presentation

A habitat suitability model constructed for the European green crab *(Carcinus* maenas) identifies potentially suitable habitats for the invasive species in coastal Alaska, British Columbia, and Washington on the basis of attributes recorded in the ShoreZone Coastal Habitat Mapping database (Harney 2007; report available online at www.coastalandoceans.com). ShoreZone data consist of along-shore coastal units and across-shore components into which the geomorphic and biologic features of the shoreline are mapped. In the habitat suitability model, nested queries of the ShoreZone database identify shoreline units possessing habitat attributes that are critica! to green crab colonization: protected or semi-protected wave exposure, mud or sand flats in the intertidal, eelgrass in the subtidal, and salt marsh vegetation in the supratidal. Each along-shore coastal unit is rated (0-4) with respect to habitat suitability for the green crab on the basis of the number of critica! habitat attributes that co-occur within a single along-shore unit. In this manner, highly-suitable habitat sites, on the order of tens to hundreds of meters in shoreline length, are identified from more than 50,000 km of coastal attribute data in Washington, British Columbia, and Southeast Alaska. In this study, 15 green crab occurrence sites on the west coast of Vancouver Island are compared to habitat suitability model predictions for the area. Ali 15 sites have a rating of at least 2 of 4 (wave exposure and at least one other attribute). Three sites have a habitat rating of 3, and four sites have a habitat rating of 4. With respect to the individual habitat attributes at these sites: Protected or semi-protected wave exposure categories are mapped at ali 15 sites (100%). Protected exposures alone account for 80% of the sites. - Eelgrass is mapped in 7 of the 15 sites (47%). - Salt marsh vegetation is mapped in the supratidal zone of 1O of the 15 sites (67%). - Sand or mud flats are mapped in 7 of the 15 sites (47%). When flats are present, eelgrass also occurs 50% of the time. When flats are present, salt marsh vegetation also occurs 70% of the time. Bare tidal flats lacking either eelgrass or salt marsh vegetation do not occur at any of the green crab occurrence locations. Applications of suitable habitat predictions include site selection for monitoring and modeling efforts. Using the highest-rated site predictions generated by the ShoreZone model (rated 4 of 4), highly suitable green crab habitat locations can be identified from thousands of kilometers of shoreline attribute data in British Columbia and Southeast Alaska, even in the absence of other data or information.

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A TALE OF TWO SEAS: ECOLOGICAL ASPITTS < >I• Ne >N INI »I< 11 Nf H I\ Allit '11 tUN-. ALONG THE COAST 01: ISIt Al·.I .

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Oral Presentation

One of the most extensively documented marine bioinvasion phenomena is the invasion of Red Sea s¡wd1·s to the Mediterranean Sea through the Suez Canal (known as "Lessepsian migration"). However, little is known about Lessepsian migration of ascidians (Phylum Chordata, Class Ascidiacea). The uniqueness of the Israeli coast line, namely the combination of a coral reef environment anda Mediterranean rocky shore only few hours apart, together with the recent (in evolutionary terms) opening of the Suez Canal, provides fertile ground for comparative studies of ascidian distribution and migration. The present study reports the occurrence of seven non-indigenous ascidian species **(NIA**'s) along the Mediterranean coast of Israel: *Ecteinascidia thurstoni, Ascidia cannelata, Phallusia ni9ra, Rhodosoma turcicum, Symplegma brakenhielmi, Microcosmus exasperatus* and *Herdmania momus.* Five of these species (excluding *P. ni9ra* and R. *turcicum)* probably reached the Mediterranean via the Suez Canal, since they have an extra-tropical Indo-Pacific distribution and a restricted distribution in the eastern Mediterranean. *E. thurstoni* is reported for the first time in the Mediterranean, and *H. momus* and *M. exasperatus* were recorded mainly on artificial substrates. In addition, in order to understand parameters that may lead to species invasions, a comparative study of the ecology of the solitary ascidian *H. momus* was conducted simultaneously in the Red Sea and the Mediterranean coast of Israel revealing marked differences in *H. momus* populations. Increased recreationa! sailing and the proliferation of marinas nd artificial marine structures in recent decades, provide additional sites for colonization ofNIA's, especially those with low dispersal abilities. The accumulating evidence for the negative impact of NIA's on local species and habitats raises the necessity for long-term studies that will combine regular monitoring of natural versus artificial habitats, and the use of molecular genetic tools that will allow the identification of sources and patterns of dispersa!.

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CURRENT SCIENTIFIC APPROACHES AND SOME RESULTS FOR BALLAST WATER MANAGEMENT IN KOREA

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Poster Presentation

Since adoption of "International Convention for the Control and Management of Ship's Ballast water and Sediments" in 2004 by intemational maritime organization (IMO), our government has taken several steps to reduce the risks arising from the transfer ofharmful aquatic organisms and pathogens via ship ballast water. As concern about biological invasions via ballast water grows, project PERAT (Port Environmental Risk Assessment Technology) began as a government program in 2007. The project was designed to develop the ballast water management program which control discharge of ballast water of ships entering harbors of Korea. Risk assessment of ballast water is inevitable when considering discharge of ballast water beyond bioregion. For implementation of risk assessment defined by G7 guideline under the Convention, port baseline surveys, survival tests, and vector analysis are inevitable fundamental stages in the viewpoint of a whole-of-port approach. However, until recently, despite growing concem about biological invasions via discharged ballast water at major ports, any attempt has not been made on discerning introduced or invasive species from the native community in Korea. Thus, as part ofproject PERAT, we have conducted port baseline surveys seasonally at major ports (lncheon, Gwangyang, Pusan and Ulsan) and listed up the species composition and abundance of planktonic and benthic community since 2007. Concurrently, we visited many ships as possible to investigate biological and environmental information inside ballastwater with a variety of ballasting source. The diverse investigation for risk assessment has been carrying out as part of currently ongoing project in Korea. We will present composition of copepods in ballast water of ships entering to Korea. Sorne freshwater and non-indigenous species *(Sinocalanus doerri, Pseudodiaptomus isbi9akiensis)* were identified.

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PARASITES OF INVASIVE LIONFISH, PTEROIS VOLITANS, NEAR LEE STOCKING ISLAND, BAHAMAS, ANO COMPARISON WITH THREE NATIVE CARNIVOROUS FISHES

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Oral Presentation

Parasites may inhibit or facilitate the success of invasive species and thus influence their impact on native communities. The Indo-Pacific red lionfish, *Pterois volitans,* has increased rapidly in abundance since being introduced in the tropical western Atlantic overa decade ago. As a first step in assessing the possible role of parasites in affecting its success, we compared the prevalence and intensity of parasite infestation on lionfish collected from natural and artificial reefs near Lee Stocking Island, Bahamas, with three other common, native, camivorous fish species: lane snapper *(Lutjanus syna9ris),* white grunt *(Haemulon plumieri),* and squirrelfish *(Holocentrus adscensionis).* We examined the extemal surface, gills, and guts of 29 *P. volitans,* and 1O each of *L. syna9ris, H. plumieri,* and *H. adscensionis.* All of the 30 native specimens had parasites in at least one of the three body regions examined, ar"i.d 33% of these had parasites in all three regions. 50 - 78% of each native species was infected with ectoparasitic monogeneans or copepods on the skin, and 80 - 100% of each was infected with gut parasites (cestodes, nematodes, and digeneans) and monogenean gill parasites. In contrast, only 10 *P. volitans* were infected in at least one of the three body regions, and none were infected in all regions. 13.8%, 27.6%, and 0% oflionfish had skin, gut, and gill parasites respectively. With one exception, none of the infected *P. volitans* had more than 3 individual parasites combined, while intensities for other species ranged from 4 to 90 parasites per infected fish. To test for differences in susceptibility to gnathiid isopods, 12 *P. volitans,* and 12 *H. plumieri* were placed in plastic mesh cages that were set on natural reef at dusk and retrieved at dawn. All 12 *H. plumieri* had 1-8 gnathiid isopods, all of which had fed on fish blood. Although *P. volitans* had more surface area per fish, only one, unfed, gnathiid was found. Thus, *P. volitans* at our study site does not appear to have specialist macro-parasites (e.g., monogenean gill worms) and appears to have low susceptibility to generalist gut and skin parasites. These factors may allow more energy to be devoted to growth and reproduction and thus facilitatc the lionfish invasion in the tropical Atlantic. Future studies will examine parasite-host interactions in the native Pacific range of *P. volitans.*

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IF YOU BUILD 1T THEY WILL COME, BUT WILL THEY SPREAD? EXAMINING HABITAT PATTERNS OF INVASIONS IN FOULING COMMUNITIES

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Oral Presentation

Artificial habitats are known to differ from natural benthic habitats in their community composition, while man-made habitats associated with vectors, such as ports and marinas, support a high diversity of marine nonindigenous species (NIS). Of the 232 NIS reported to be associated with hard substrata in North America, 86% have been recorded from artificial structures. This high prevalence of NIS in artificial environments probably stems from a real relationship between habitats, vectors, and species invasions, but also from a preponderance of studies that focus on unnatural sites. A review of the literature reveals that for fouling NIS, there is an absence of data from natural hard-substratum habitats, thereby hindering our understanding of their spread into natural systems. In British Columbia, the distribution of most NIS has only recently been examined regionally and much of this research has targeted artificial habitats (e.g. ports, marinas and aquaculture facilities). To determine whether NIS are spreading beyond artificial structures, we conducted <living surveys at seven marinas and adjacent natural rock habitats on Southern Vancouver Island. At each site we quantified the abundance and distribution of non-native tunicate species using in-situ counts and digital photographs. Our results showed that although severa! non-native tunicates were present at marinas, only the introduced colonial violet tunicate, *Botrylloides violaceus,* was present in significant numbers in natural rocky habitats. We are currently investigating the role of propagule pressure and post-settlement mortality as underlying processes behind these contrasting distribution patterns. Although marine invasions are often cited as a threat to native biodiversity, our field data and a review of the literature suggest that for fouling communities, more focus on direct sampling of natural habitats is required before this statement can be directly confirmed.

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VALIDATING BALLAST WATER TREATMENTS TO REMOVE POTENTIAL INVADERS FROM DISCHARGE

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Poster Presentation

The Maritirne Environ rnental Resource Center (MERC) is a State of Maryland initiative providing test facilities, inforrnation, and decision tools addressing key environrnental issues facing the rnaritirne indus try. A prirnary focus is evaluation of rnechanical and biological efficacy, costs, and logistics of ballast water treatrnent systerns, along with econornic irnpacts of regulation and rnanagernent approach. Additional analyses are planned to evaluate rnanagernent strategies that reduce biofouling and associated invasion risk. A description of MERC structure, products, and services can be found at www.rnaritirne-enviro.org.MERC draws expertise and resources frorn University of Maryland Center For Environrnental Science (UMCES), Srnithsonian Environmental Research Center (SERC), University of Maryland, and the Maritirne Administration (MARAD). Initial MERC treatment testing utilizes a modified ballast system aboard the MV Cape Washington (a MARAD ready-response fleet vessel) in the Port of Baltimore. The test systern employs pre-existing ship pumps and tanks to move and store ballast water under realistic conditions, is designed so treatment modules rnay be interchanged readily, and can conduct one complete test trial/ week. Five to six trials for each treatment type evaluated are typically conducted to determine if the specific treatment can meet current International Maritime Organization (IMO), and future US, standards. Sarnpling and analyses conform to methods and guidelines recommended, or being developed, by IMO and the US Coast Guard (through EPA Environmental Technology Verification program). Various parameters of initial challenge water, control ballast water, and treated ballast water are quantified, including physical conditions (e.g., total suspended solids, ternperature, dissolved oxygen) and biological conditions (e.g., biota >50-µm, 10-50-µm, bacteria). Sampling occurs upon filling of control and treated tanks and upon discharge (after 5 days) to establish treatment efficacy. What follows is a concise guide to MERC ballast-water-treatment-technology evaluation and validation. Our goal is to provide the rigorous, independent data and decision tools that are required by treatment developers/vendors, regulatory agencies, classification societies, and ship owners/ operators to address the issue of ballast water invasivespecies.

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MOLECULAR DETECTION OF POTENTIAL HIGH RISK MARINE PEST SPECIES FOR NEWZEALAND

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Poster Presentation

The movement of invasive species around the world by human-mediated mechanisms has had major impacts on marine ecosystems. Transport of planktonic organisms and larvae via ballast water has been implicated in the introduction of several invertebrate species. The ability to quickly and accurately identify larval and planktonic stages in ballast water and environmental samples is crucial for the early detection of potential pest species. However, these life stages are difficult to identify to species leve! using morphological characteristics. We aimed to develop species-specific molecular assays for species deemed potentially high risk pests to the New Zealand environment. We have developed and adapted two molecular methods for hvo species, *Asterías amurensis* and *Corbula amurensis,* which are declared Unwanted Organisms under New Zealand law. Both species have been associated with ballast water introductions in other countries.

We adapted two methods for the detection and identification of *A. amurensis.* Firstly we designed and tested sandwich hybridisation assay (SHA) probes targeting the 1SS rRNA, a region commonly used for dinoflagellates. However this region did not show enough variability to discriminate closely related species. A second SHA assay was designed targeting the ITS rRNA region. This region has never been used previously for a SHA. This assay could discriminate aga.inst closely related species and had a level of detection (LoD) of approximately 15 larvae. Additionally, as the SHA targets rRNA, which degrades relatively quickly, assay results are a good indicator of organism viability. We have also adapted a real-time PCR assay for *A. amurensis far* the New Zealand environment, targeting the mitochondrial cytochrome-c-oxidase-1 (mtCO 1) gene. The assay was optimised for our laboratory' s real-time PCR machine and tested for cross-reactivity against closely related New Zealand species. No other species gave positive results and the LoD was less than one larva. Both of these assays have also been optimised using tissue samples to also identify adult specimens. We have designed a real-time PCR assay for C. *amurensis* targeting the mtCO1 gene and cross-reactivity testing is underway. We also aim to designa SHA for this species. Both assay formats have rapid protocols and can potentially be adapted for portable and multi-species options.

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MOLECULAR IDENTIFICATION ANO POPULATION GENETICS OF A COLONIAL ASCIDIAN (DIDEMNUM VEXILLUM) IN NEW ZEALAND

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Oral Presentation

Determining whether a putatively newly-introduced species is indeed non-native or rather a previously unreported indigenous species is sometimes problematic, particularly if taxonomic assignments are based solely on highly variable morphological characteristics. Correct identification of new species is critica! for a rapid response and possible prevention of spread if a new species is considered potentially invasive. In the marine environment new colonizers may often go unnoticed in benthic environments particularly if the species is morphologically indistinguishable from a native species or lacks obvious morphological characte1istics affording easy identification.

Ascidians are common invasive species in marine environments around the world, including New Zealand. The ascidian *Didemnum vexillum* was first identified in New Zealand in 2001 in ports in the North Island . Soon after, the same species was reported in the Marlborough Sounds (South Island) where it quickly spread to mussel aquaculture areas. The species was identified, using morphological characteristics, as *Didemnum vexillum* and declared a native species, a status disputed by many at the time. Identification of ascidians in the genus Didernnum is problematic dueto the small sizes of zooids, larvae and spicules of most species, as well as poor preservation techniques and inadequate sampling. This work describes the use of the 'barcoding' mitochondrial gene, cytochrome oxidase 1 (mtCOl), for the unambiguous identification ofthe D. *vexillum* in New Zealand. Associated molecular phylogenetic analyses placed populations of D. *vexillum* in New Zealand in the same clade as other populations around the world and confirmed that D. *vexillum* should be classified as a non-indigenous species in New Zealand. This interpretation receives additional support from the relatively low mtCOl haplotype diversity amongst D. *vexillum* in New Zealand indicating a 'genetic bottleneck' possibly associated with recent colonization. These findings have significant implications for any efforts to mitigate negative affects that D. *vexillum* may have on the New Zealand aquaculture industry.

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THE ROLE OF PHENOTYPIC PLASTICITY IN MARINE BIOLOGICAL INVASIONS

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Oral Presentation

Although environmentally induced responses in marine organisms are commonplace, the importanc e of adaptive phenotypic plasticity in marine biological invasions has received little attention. 1n a review of 63 studies documenting phenotypic plasticity in marine settings, only 12 (19%) examined nonindigenous species and in several of thes e studies, the exotic status of the organism was incidental. The phenomenon, however, deserves greater attention, because phenotypic plasticity gives an organism the flexibility to match its phenotype to its new environment. As such, phenotypic plasticity can provide a mechanistic explanation to understand and predict: (1) why and how sorne individuals or species invade and others do not, (2) what the ecological effects and eventual ranges of the invader might be, (3) how native species might respond to an introduction, and (4) how spatial or temporal pattems (e.g., in morphology) develop after an invasion. Here I describe examples of phenotypic plasticity' s role in marine bioinvasions and identify areas where additional research is needed. Phenotypic plasticity has the potential to affect all stages of an invasion (i. e. , uptake, transport, establishment, integration), to enhance survival in both shipping and non-shipping vectors, and to be expressed in diverse taxonomic groups. To date, plasticity studies hav e focused only on the post-invasion phase (and, in doing so, ignored vector type), and studi es have been limited to benthic forms [molluscs (6 studies), green alga (2), cordgrass (1)]. More attention should be devoted to phenotypic plasticity's role early in the invasion sequence, on major vectors such as shipping, on common invasive taxa (e .g. , cru staceans, annelids), and on planktonic and nektonic forms. General cues that have induced post-invasion changes include food resources, physical factors (temperature , salinity, light, wave action, substratum type), and consum ers, and these cues, in tum, have elicited physiological, behavioral, morphological, and life history responses. The most comprehensive examination of phenotypic plasticity' s post-invasion influence has involved the European green crab *Carcinus maenas* in the northwestem Atlantic Ocean. Here, studies suggest the green crab's arrival has initiated an ecological arms race with native molluscan pr ey, induced changes with community-wide effects, and generated broad scale spatial and historical patterns of phenotypi c variation. Our understanding of phenotypic plasticity' s role in invasions would benefit by expanding studies to include other taxa and systems, by assessing the effects of multiple cues on phenotypic variation, and by using this information to predict an invader's ecological impact and geographic range.

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HOW DO SPREAD RATES AND IMPACTS OF MARINE RANGE **EXPANSI< >NS** COMPARE TO THOSE OF NON-NATIVE SPECIES INVASIONS?

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Oral Presentation

Shifts in species' ranges are a predicted and realized effect of global climate change; however, few studies have addressed the consequence of such shifts, particularly in marine systems. Given ecological similarities between expanding and invading species, we examined how our understanding of range expansions may be informed by the more established study of species invasions. Our review and meta-analyses revealed that (1) spread rates of expansions are lower than those of invasions, (2) marine expanders spread faster than terrestrial expanders, and (3) directions of community effects are largely negative and magnitudes are often similar for expanders and invaders, although this comparison is limited by few data for expanders. Because invasions are considered one of the primary threats to biodiversity, it follows that, like invasions, expansions have the potential to seriously affect biological systems.

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IMPACTS OF A BIOINVADING PREDATOR IN THE CALIFORNIA CURRENT

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Oral Presentation

Are species that shift or expand their ranges in response to climate change considered bioinvaders? As global ecosystems are modified by climate change, mobile species are thought to shift or expand their ranges in order to remain within their environmental tolerance limits. If the migrating species in volved are predators, trophic effects on the ecosystems invaded would be expected. Dosidicus gigas (Humboldt squid) is a large, pelagic predator that is fast-growing, short-lived, highly fecund and capable oflarge-scale migrations. Native to the eastem Pacific Ocean from Mexico to Chile, Humboldt squid have greatly expanded their range over the last decade: they are now seasonal residents in Monterey Bay, California, and have been reported as far north as southeast Alaska.

Impacts of Humboldt squid on the California Current System are being addressed in part through diet analysis, reproductive capabilities and abundance. Diet analyses show that they consume larger, longer-lived ecologically and economically important species than in their home range. Although the squid appear to be biologically capable of spawning in cold waters, lab studies have indicated that paralarvae do not develop properly at such temperatures, and none have been found off California. Thus, adult (~ 1.5 m) squid appear to forage seasonally off California but may not contribute paralarvae back into the food web. ROV transects by MBARI show that the abundance of Humboldt squid in Monterey Bay has fluctuated since the 1997/ 1998 El Niño, with adults present year-round since 2002 and peaking in *200S.* Efforts are ongoing to accumulate commercial fisheries bycatch and recreational landings data for additional estimates of population size. These abundance estimates and dietary data will permit a realistic assessment of the trophic impact of this invading predator species.

Data from Humboldt squid fitted with archival pop-up satellite tags off California reveal diel migrations from ~300 m during the daytime to 50 mor less at night, similar to that observed in the Gulf of California, Mexico, where they utilize the upper region of the oxygen mínimum layer (OML). The question ofhow Humboldt squid use of the OML off California is of interest, because this hypoxic midwater environment has been intensifying, expanding and shoaling off California over the last several decades. The OML is an oceanographic feature dosely tied to surface productivity, and thus understanding the relationship between Humboldt squid and the OML off California could provide insight into midwater climate change in relation to recent range expansion . Understanding Humboldt squid behavior and ecology in new habitats that are invaded during range expansions is critical to predicting further impacts of this squid on our ecosystems. It will also revea! features of pelagic predators that will be relevant to success in a time of climate change.

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A STAGE-STRUCTURED, TEMPERATURE-DEPENDENT MODEL OF INVASIVE COPEPODS: IMPLICATIONS FOR PSEUDODIAPTOMUS MARINUS

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Poster Presentation

The invasive copepod *Pseudodiaptomus marinus* has successfully established itself in ports along the North American west coast from San Diego to Puget Sound. The copepod outcompetes native species, affecting local food webs and ecological diversity. Here we introduce the first stage-structured model for the invasive copepod *Pseudodiaptomus marinus.* We parameterized the model using data from previously published laboratory studies, including data on the effects of temperature on development and fecundity. W e tested different temporal presentation pattems of temperature variability, including daily, weekly, and seasonally, to determine whether the different pattems affected long-term population viability and therefore invasion success in Canadian ports. We will use results from our model analyses to guide laboratory experiments aimed at testing hypotheses about the effects of stochastic temperature variability on invasion success with relation to copepod stage.

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A PLAN FOR ERADICATION OF NON-NATIVE SPARTINA FROM THE WEST COAST OF THE USA BY 2018

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Oral Presentation

Four species of non-native cordgrasses (genus *Spartina)* are found along the West Coast of the United States and Canada. Where established, these invaders convert estuarine mudflats and salt-marsh ecosystems into uniform Spartina meadows and alter estuarine hydrology through sediment accretion. Drift card studies suggest that widespread dispersa! of seeds and fragments can occur along the West Coast. Therefore, eradication efforts in one area may be negated by propagule pressure from outside the area. Through the West Coast Governors' Agreement on Ocean Health, the Governors of Washington, California, and Oregon committed to work cooperatively to eradicate non-native Spartina by 2018. An Action Coordination Team (ACT), or workgroup, was been formed to develop a strategy to meet the 2018 goal. The ACT included representatives from the three states, federal government, tribal govemments, non-governmental organizations, and the Province of British Columbia.

The Plan is divided into six elements: prevention, early detection, rapid response, eradication, restoration, and communication/public outreach. The successful eradication efforts in San Francisco Bay and Willapa Bay have required significant funding. Ongoing efforts to eradicate Spartina in Willapa Bay and San Francisco Bay have cost $12 million. Early detection of new infestations is critical to economical eradication of Spartina on the West Coast, and the Plan focuses on early detection and rapid response as well as support of ongoing efforts.

The cost of Plan implementation over the next three years (2009-2011) was estimated at approximately $8 rnillion. The total new funding required to meet the 2018 eradication goal is $ 25 million dollars over the next 1O years. The ACT will pursue this funding through a variety of sources, including state, federal, and non-governmental organizations.

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ASSESSING RAPID-EVOLUTION OF THE CI-IEMI CAL HH '<H;NITI< >Ne 11 I\N INVASIVE CRAB SPECIES IN TASMANIA

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Poster Presentation

The study of predator-prey relationships, competitive interactions, and the ecological change of local communities are necessary for a thorough understanding of the impacts of invasive species. *Carcinus maenas,* the European green crab, has successfully invaded five temperate regions outside its native range. In this study we determine if populations of the Australian whelk, *Lepsiella vinosa,* from three regions with different histories of exposure to C. *maenas* invasion (> 100 yr, 15-20 yr, no C. *maenas)* have different morphological defenses or behavioral responses to C. *maenas.* The morphology of *L. vinosa* was measured to determine if history of predation by C. *maenas* has resulted in different whelk morphological responses. Shell length, shell width, aperture length, aperture width, lip thickness, and tissue mass were all quantif'ied. Behavioral responses, were quantified by measuring predation rates of *L. l'inosa* on mussels when exposed to C. *maenas* anda native crab. This experiment was run in mesocosms in which we replicated the presence of C. *maenas* or the native crab with *L. vinosa* collected from 4 sites from each of the three regions with different histories of invasion. Predators were confined to cages and snail density was identical in ali treatments, so any effects of the predator were mediated through behavioral trait shifts induced by chemical cues. W e will discuss changes in morphology and behavior in the context of the C. *maenas'* invasion.

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GEOGRAPHIC AND QUANTITATIVE PATTERNS OF BALLAST WATER MANAGEMENT IN CALIFORNIA: 2002-2009

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Oral Presentation

For nearly a decade, the California Marine Invasive Species Program (MISP) has overseen the state's program to prevent nonindigenous species introductions to California waters through the commercial shipping vector. During that time, laws for the management ofballast water have evolved with emerging knowledge. For example, the requirement to exchange ballast water before discharging in California was expanded in March of 2006 to include vessels arriving from both within and without the U.S. Exclusive Economic Zone.

Vessels arriving to California ports are required to submit ballast water reporting forms detailing ballast management activities to the MISP. Information required by these forms comprise a data-rich, extended time series through which the MISP can track compliance with California ballastmanagement regulations, and can develop more effective management measures. The data also allows for the geographic and temporal examination of source and exchange patterns for ballast water that is eventually discharged within the state.

This talk will present analyses of ballast water discharged in California through time, within the context of the changing regulatory landscape. Analyses will examine quantities and geographies ofboth properly and improperly managed ballast water, where such ballast water has been exchanged, and where it has been discharged. Data will also be presented on compliance patterns throughout the time series. Such analyses may provide valuable information that can inform both retrospective and predictive studies of NIS invasion patterns.

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BIOLOGICAL UNCERTAINTIES AND BALLAST WATER MANAGEMENT: WI-ILN ONE SIZE DOES NOT FIT ALL.

Tavares, Joana Flor, Hawaii Division of Aquatic Resources,Honolulu, HI 96813 USA

Oral Presentation

In an attempt to reduce aquatic invasions, the IMO's Ballast Water Convention and national and regional ballast water regulations have established performance standards measured in maximum concentration of' organisms that can be discharged into coastal environments. However, the implementation of these performance standards and the development of appropriate treatment technologies are hindered hy the many uncertainties intrinsic to the biology of invasions and shipping industry behavior. While information about the volume, frequency, source and entrainment time ofballast water discharges of all vesscls calling US ports is available through mandatory reporting to the USCG/NBIC, knowledge about quantity ancl quality of populations being discharged by ships' ballast water is precarious. Empirical studies have shown that significant variability exists in composition, abundance and survival ofballasted organisms among voyages and among tanks of the same vessel. In this presentation, I explain how biological uncerlainl h·s stll'li as seasonal variation in the concentration of organisms in ballast water source locations ancl clil'fi.·n·nl survival rates of entrained populations affect the extent to which ballast water must he trcatecl lo 1111·c·I performance standards. I use geo-referenced seasonal ocean color data from SeaWiFS as a proxy l'nr 11111 l,d concentration of organisms entrained in ballast water, and propose an alternative population cly11,111ilc· model for these organisms based on their probable response to entrainment time ami autolrophic heterotrophic interaction. I combine the concentration data and population dynamics ffi()(h•l with h,,ll,, 1111¡ ¹ data from NBIC and use an optimization model to explore management scenarios. I show th,11 111111111111111 ballast water treatment efficacy can vary greatly among journeys, seasons and among tanks witl1i11 tllC' ,11111· vessel, and that in many cases, treatment efficacy would have to be extremely high (>99.t)cV.,) i111111 l1·1 11, meet performance standards. These results show that ballast water regulations, manag\'1111·111 ¡,1'111111 111 „11,I treatment technology must be evaluated in light of these uncertainties.

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IMPACTS OF AQUATIC INVADERS ON NATIVE BIOTA

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Oral Presentation

Non-native invaders may compete with, eat and infest native species, reduce biodiversity and homogenize biota. These reported 'negative' effects can be based on qualitative observations, quantitative correlations or manipulative experimental data. However, these types of studies have different strengths and weaknesses and should only be compared critically. We will provide a quantitative assessment of the experimental evidence for invasion impacts in aquatic ecosystems focusing on out-doór experiments where the abundance of the invader has been manipulated. At the time of abstract submission, Hedges effect sizes (ES) have been extracted from 116 peer-reviewed research papers, covering more than 50 aquatic invaders and containing ca. 3500 extracted within-study ESs. A hierarchical approach to ES estimation, that include non-independent within-study ES, average ES for individual studies, and cumulative ES that average data across studies, is being used to compare impacts between invader types and habitats. Preliminary analysis (work in progress) indicates that negative effects on native biota are larger for animals than plants, mobile than sessile organisms and freshwater animals compared to marine animals (hardly any outdoor experimental freshwater plant invasion impact studies exist). We have also detected many 'positive' effects on native biota, typically being associated with habitat formers such as seaweeds and reef-formers or indirect trophic effects (e.g. via cascades). Ongoing analysis to be presented will include impact tests of functional groupings of both the invaders and the natives (prey, predators, competitors, mutualist, etc.), the importance of experimental design (e.g. caging vs. non-caging, addition vs. removal methods), test- duration and location (spatio-temporal context), and the relative importance of invaders vs. other orthogonal test-factors (e.g. fertilization, shading, adding native conspecifics) . We will also use the data to rank the invaders according to effect sizes, discuss if our quantitive ranking match perceived 'worst' invaders, e.g. as listed in the 'GISP 100 worst invaders' booklet, and outline contemporary experimental research gaps.

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INVASIONS OF A UNIFORM HABITAT BY A DIVERSE SPl:Cll:S COMl'll-.X; I INKINt; COLONIZATION ANO INVASION ECOLO<;Y

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Oral Presentation

lnvasion and colonization ecology has taken disparate research directions despite covering the same general topie; how species colonize space. We target this research gab by quantifying colonization of native *Caulerpa* seaweeds on subtidal temperate reefs in Western Australia, within an invasive species context. A survey documented the presence of 11 *Caulerpa* species within a single uniform habitat; kelp dominated subtidal reefs (9 reefs at 10 m depth along 600 km coastline). Kelp clearance experiments, manipulating disturbance intensities, extents and frequencies, showed that all but one species invaded disturbed plots overa 3 year period (and the 11th species did indeed survive and maintain a population for > 2 years after being transplanted into disturbed plots). Typical guerrilla morphologies were early colonizers typically found in small colonies, wh reas phalanx forms were late colonizers but found in large colonies. We are not aware of any other biological system where 11 morphologically similar conspecific taxa have been reported to colonize small plots in a uniform habitat (total experimental area < 1000 m2). Ongoing work aim to match the molecular, morphological, and functional traits of the 11 species to habitat characteristics, to provide a general test of the invasibility vs. traits paradigm. We suggest that this system provide a unique test of the relative importance of species traits, system characteristics and propagule pressures in determining invader success, with only low molecular auto-correlation between invaders. Our study also show that *Caulerpa* colonizers from Western Australia only survive in disturbed habitats asan inferior group of competitors - in contrast to what is suggested for *Caulerpa* invaders in seagrass beds in many parts of the world.

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CHARACTERIZATION OF ANTIBIOTIC RESISTANCE IN VIBRIO CHOLERAE ISOLATED FROM SHIPS' BALLAST AND OTHER ENVlRONMENTAL SOURCES

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Oral Presentation

Ships' ballast has been implicated as a vector in the dispersal of invasive species into new environments. Numerous cases have been documented for the introduction of macroorganisms via ballasting operations, but what is less known is the role of ballast water and residuals in the spread of potentially harmful microbes, especially with reference to novel genotypes. Of particular interest are the genes encoding for various forms of antibiotic resistance, many of which are carried on mobile genetic elements. A four-year sampling effort has yielded over 300 putative i olate - of Vibrio cholerae from ships' ballast tanks and various environmental sources, of which 189 have been profiled fo r antibio tic u cep tib ilit y using twelve diverse antibiotics . The results demonstrate widespread resi tance to b-lactam antibioti s (67%), especially in nearshore i olat c a com parecl to tho e isolates derived from ships' ballast tanks. Plasmid extractions and restriction enzymc analy e ha ve how n evidence of plasmids of approximately 38 and 23 kbp in many of these isolat e , sugge ting thc potential for horizontal gene transfer (HGT). Additional work using restriction fragment length polymorphisms and PCR for specific antibiotic resistance genes has yet to reveal the genetic source of the observed antibiotic resistance. Knowledge from this study and future microcosm experiments will help to ascertain the potential for HGT in a ballast tank setting.

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SEA BASS (DICENTARCHUS LABRAX) ESCAPED FROM FISH FARMS IN CANARY ISLANDS, A NEW STEP TO THE ESTABLISHMENT OF SELF-REPRODUCING PO PULATION IN CENTRAL ANO WESTERNMOST ISLANDS?

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Poster Presentation

The introduction of non indigenous and/or locally absent species is a growing concem in the coasts all around the world. Sea bass *(Dicentrarchus labrax)* is cultured in Canary Islands and it is considered an introduced species in Gran Canaria, Tenerife and La Palma. We have studied abundance in the wild, size frequency, stomach contents and gonadal maturity. Densities of sea bass can reach 8. 16 individuals per 100 m2 at localities near fish farms. The escapees sizes were between 15 and 65 total length (TL). Up to now a total of 64 sea bass have been captured by spearfishing. The stomach content shows that its diet is mainly based on fishes. Gonadal analysis demonstrate that escap d sea bass ofboth sexes reach maturity in natural conditions. A total often gravid sea bass (one female and nine males), all larger than 40 cm TL, were captured from January to February 2009. Therefore escaped sea bass are established in the wild and can exploit natural resources successfully. Moreover this species could maintain self-reproducing populations in coasts where historically populations of sea bass did not exist. Further studies are required on the fertilization success and potential reproduction events in the fish cages.

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ELUCIDATING ENEMY RELEASE STRATEGIES OF INVASIVE MACROALGAE IN THE MEDITERRANEAN SEA

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Oral Presentation

Enemy release hypothesis predicts the success of introduced species by escaping novel enemies. The Mediterranean Sea homes a very low diversity and abundance of herbivores, which may explain the invasive success of numerous introduced macroalgae, which have strong deleterious impacts on the native seagrass and alga! communities. The interactions between invasive algae and native fauna are !argely unknown in the Mediterranean, although recent studies show that sorne herbivores are capable of ingesting the invasive *Caulerpa racemosa,* yet they are not able to limit its spread. We examined the feeding behaviour of the main invertebrate herbivore in the Mediterranean, the sea urchin *Paracentrotus lividus,* against the most invasive macroalgae in the Western Mediterranean *(Caulerpa racemosa v. c_ylindracea, Lophocladia lallemandii, Womersleyella setacea,* and *Acrothamnion preissii)* by conducting paired feeding preference experiments . We observed that the sea urchin preferred the native seagrass *Posidonia oceanica* in ali cases, except when offered C. *racemosa.* In addition, we performed a no choice feeding experiment where sea urchins were fed one species of macrophyte (C. *racemosa, L. lallemandii* or *P. oceanica)* far 3 months, and we quantified feeding rates and impacts on urchin fitness. The no choice experiment supported the paired experiments, suggesting that C. *racemosa* is a highly preferred species (ca 90 % biomass eaten), while *L. lallemandii* is much more avoided (ca 40% eaten). Although C. *racemosa* is highly preferred, it significantly reduced sea urchin fitness. In contrast, urchins feeding on native seagrass were the healthiest. Analyses of plant traits suggest that feeding behaviour of sea urchins is mediated more by physical and chemical defences of macrophytes rather than by nutritional quality. While three invasive species escape from enemies by reducing their preference, C. *racemosa,* a highly preferred species, escapes enemies by reducing herbivore performance, explaining why this species it is not limited by grazing in the field. Our findings not only improve the understanding of the effects of invasive species on native fauna, but also provide essential insights far understanding invasion mechanisms and thus far developing adequate management strategies.

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BALLAST WATER RISK ASSESSMENT FOR SAIGON PORT, VIETNAM

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Oral Presentation

Rapid economic growth happened in Vietnam during the past decade has resulted in high volume of ship traffic and ship ballast water exchange at majar ports in Vietnam. Sai gon port - Ho Chi Minh City, is the largest port in Vietnam and one of the busiest ports in Southeast Asia. Since 2007, the first ballast water risk assessment in Vietnam has been conducted at Saigon port. Records of ships entered Saigon port during 1999 - 2008 were analyzed to determine patterns of ship traffic in and out of Saigon port during the past ten year and to estimate the volume of ballast water exchanged. Samples of ballast water were collected from 200 ships during 2008 for the identification of plankton species transported via ships' ballast water to Saigon port. The IMO's ballast water reporting procedure was also applied to ships coming to Saigon port on a trial basis during the course of the study. Feedbacks from that trial will be used to improve ballast water management at Saigon port to comply with IMO's guidelines.

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ENVIRONMENTAL FACTORS INFLUENCE POPULATION DYNAMICS OF THE MITTEN CRAB, ERIOCHEIR SINENSIS, IN SAN FRANCISCO BAY

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Oral Presentation

The Chinese mitten crab, *Eriocheir sinensis,* was discovered in the San Francisco (SF Bay) in 1992 . Since its invasion, the mitten crab has become a nuisance species, threatening native species and physical structures. Expansion throughout this waterway potentially has negative effects, through competition and predation, on native species of the area. The explosion in adult populations and successive collapse in invasive species are indicative of complex population dynamics. If these population explosions can be predicted, preparations can be made for the negative effects caused by the clown stream migration of mitten crab juveniles. Year-class strength of juveniles may be predicted by zoea or megalopae abundance,_ in correlation with temperature, salinity and tidal currents. These abundances can be deterrnined with light traps and plankton tows. Previous studies suggest a thermal tolerance of 1 2 C limits mitten crab larval survival. W e previously created a key to identify crab zoea of the region and have recently developed a dichotomous key to identify the megalopae species in the SF Bay /Delta system. The objective of this study is link the numbers of zoea and megalopa with the adult populations found in SF Bay. Plankton tow samples from the California Department of Fish and Game taken from the northern region of the SF Bay during 1998 -2008 were analyzed. In addition, the light trap samples were taken from areas in the San Francisco Bay /Delta system. Including E. sinensis, ten species ofbrachyuran zoeae and megalopae were collected from light trap and plankton tow samples and keyed to species to determine abundances. Mitten crab megalopae were found in light trap samples taken during April 2007-May 2008. Point San Pablo possessed the highest number of E. sinensis megalopae in light traps. Zoea abundances vary greatly; in 2003, months with peak abundance hada zoea CPUE between 458 and 4035. Although mitten crab zoeae declined rapidly after 2003, the levels never reached zero. In 2006 and 2007, months with peak abundance hada CPUE of 9.8 and 8.1, respectively. Our data support zoeae thermal intolerance below 11.7 C and salinity below 23.2 psu. These abundances indicate a significant drop in numbers but suggest that sufficient individuals are present to cause additional population explosions.

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NUTRIENT LOADING AND BENTHIC NATIVE-INVASIVE SPECIES DYNAMICS

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Oral Presentation

The effects of nutrient loading on the success of biological invasions are best understood in terrestrial systems, where studies have generally shown that increased nutrients facilitate the spread of invasive plants. To date, these relationships have remained largely unexamined in marine systems and at higher trophic levels. We conducted studies to examine the effects ofinteractions between nutrient loading and invasion by the invasive mud snail, *Ilxanassa obsoleta*, on the native mud snail *Cerithidea californica*, in San Francisco Bay, CA. Where both species coexist, *llyanassa* has been documented to competitively displace *Cerithidea* through behavioral interactions as it migrates from mudflat to marsh. Using a complete factorial design, we experimentally manipulated densities of *Cerithidea* and *llyanassa* as well as nutrient levels at two tidal elevations (high = unvegetated marsh; low = mudflat) to investigate the role of nutrients in invasion success in this system. Response variables included changes to microalgal community composition, snail growth and mortality, stable isotope signatures, and sediment organic matter and carbon :nitrogen ratios. Results indicate that nutrient additions increased microalgal (diatom) biomass at both tidal elevations. Both species grew most in the low-density, single-species treatments and least in the two-species (high density) treatments, confirming negative interspecific interactions. The native snail grew significantly more than the invasive snail on the marsh ($p = 0.00$), where it is generally found in higher densities. Similarly, the invader grew significantly more than the native on the mudflat ($p = 0.00$), where its densities are generally higher. Nutrients increased growth in both species but did not alter this "home team" habitat advantage. However, nutrients did significantly increase growth of the native on the marsh compared with the mudflat ($p = 0.01$). Without nutrients, *Cerithidea* growth on the marsh was not significantly greater than on the mudflat, suggesting that nutrients provide a refuge for the native in this habitat. While nutrients consistently benefited *Cerithidea* with regard to growth, they harmed *Ilyanassa* with regard to mortality. Overall, nutrients significantly increased mortality of the invader ($p = 0.01$) but did not affect native mortality. This effect was most pronounced at high tidal elevation. While the literature initially supports competition and nutrient facilitation, I will present a review of these interactions across systems. In summary, these results indicate that nutrients in soft sediment benthic systems can play an important quantitative role in determining invasion success at higher trophic levels by affecting competitive dynamics between native and invasive species but their qualitative impact is context-dependent.

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EFFECT OF SHARED EVOLUTIONARY HISTORY ON THE ABILITY OF ONE NATIVE ANO TWO INVASIVE WHELKS TO ADAPTTO NOVEL PREY

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Oral Presentation

Interactions between invasive and native species, and between invasive species from different regions, can be unpredictable. In predatory interactions, a lack of shared evolutionary history may produce a highly asymmetric relationship. Since novel adaptations can give an invasive species a competitive or predator advantage, any asymmetry is often assumed by evolutionary ecologists to be aiding the invader. Invasive predators are presumed to have more success on novel prey than native predators. This paradigm predicts that invasive predators are frequently successful at incorporating native prey into their diets, while native predators are rarely successful at recognizing or handling invasive prey. However, there are also numerous examples of biotic resistance, when novelty aids a native predator in controlling the spread of an invasive prey species. We have exarnined the extent to which shared evolutionary history determines the predation success of native and invasive predators on familiar and novel prey in three whelk species found in San Francisco and Tomales Bay. *Acanthinucella spirata, Ocinebrellus inornatus,* and *Urosalpinx cinerea* success on familiar vs. novel prey items was tested. We offered each whelk various species of mussels, oysters, and bamacles in pairwise trials, and also measured handling time for each predator on each species. We also tested whether a predator may increase its facility over time in recognizing and handling novel prey by comparing *U. cinerea* from the East Coast of the USA populations to *U. cinerea* from the West Coast. **W**est Coast *U. cinerea* have had decades or centuries to adapt to native West Coast and Asían prey species, while East Coast *U. cinerea* have not.

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MOLECULAR ECOLOGY OF THE BARNACLE MEGABALANUS COCCOPOMA OVER ITS INTRODUCED RANGE IN THE SOUTHEASTERN U.S.

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Oral Presentation

Invasion ecology is emerging asan increasingly important field as the impacts ofhuman activities on the envíronment are realized by the world. The advent of advanced molecular tools provides a way to gain insight on the realized and potential dispersa! of introduced species globally. The recent arrival of the titan acorn barnacle, *Meaabalanus coccopoma,* a tropical Pacific species, to the southeastern coast of the United States presents an opportunity to study the dynamics and limits of its establishment and expansion northward through the use of these molecular tools. Thermal stress is a likely determinant of the geographic range of this species anda factor of potential differentiation among populations. DNA sequencing and phylogenetic analysis were used to characterize population genetic structure of this barnacle across its introduced range. Western-blot immunochemical assay were used to a e the heat-shock protein to ubiquitin ratio in individuals which can be used as a proxy for the amount of stress an organism experiences. By coupling population structure and protein expression with thermal oceanographic data, this study tries to make projections on the potentia! range expansion of *M. coccopoma* along the eastern coast of the United States.

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IS THE RIGHT MESSAGE REACHING THE AUDIENCE?

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Oral Presentation

As concem in invasive species grow, it is important far us to ask whether the message is reaching the right audience. This paper argues that it is justas important to ask: Is the right message reaching the audience? Invasion ecology is no stranger to the charges ofbeing xenophobic and alarmist science. We would like to think that such responses are the result of ignorance and/or an incomplete understanding of the underlying issues. But despite repeated denial and extended responses from prominent invasion ecologists, this perception has not gone away. Why does the perception of racism and paranoia in invasion ecology persist?

This paper will examine U.S. newspaper coverage of two species - the Chinese Mitten Crab *(Eriocheir sinensis)* and the Northem Snakehead *(Channa ar9us)* - as case studies far understanding the message that is being communicated to the public. I will use media content and discourse analyses to reveal the explicit and the implicit assumptions inherent in these articles.

While it is often argued that science and media are very different and separate entities - which they are - we cannot deny the importance of the media in communicating infarmation to the public. The media is gatekeeper of information. If the media - not ecologists - are communicating xenophobic elements and/or inaccurate information in their write-ups about invasive species, should ecologists take them to task? What responsibility do ecologists have in ensuring that the "right" message is communicated to the public?

There is little argument that invasive species is one of the greatest threats to biodiversity, but how do we ensure that the urgency of the issue is communicated without expanding energy to defend the science against charges of xenophobia? How can we advance communication without disenfranchising ethnic communities?

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CHANGES IN PATTERNS OF SELECTION ON A NATIVE SPECIES FOLLOWING INVASION BY A HABITAT-FORMING SEAWEED

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Oral Presentation

Habitat-forming invasive species cause large, novel changes to the abiotic environment. These changes provide new selective regimes for native fauna, yet little is known about how pattems of selection on native fauna differ between uninvaded and invaded environments. In southeastem Australian estuaries, the habitat-forming invasive seaweed, *Caulerpa taxifolia,* forms dense beds causing two majar abiotic changes compared to uninvaded areas: strongly anoxic sediment and low dissolved oxygen water which frequently reaches hypoxic levels. The native bivalve *Anadara trapezia* recruits into *Caulerpa* and although it suffers lower survivorship, growth and reproduction in that habitat adult clams can persist for greater than five years there. In this study, we compared patterns of selection on *Anadara* between Caulerpa-invaded areas and uninvaded unvegetated areas. We transplanted *Anadara* recruits into both habitats for 18 months and fitted multiple regression models to estímate directional (linear), quadratic and correlational (non-linear) selection on morphological traits (shell dimensions, gill weight and palp weight) using biomass as a proxy for fitness. We found important differences in selection between habitats with evidence for directional selection on single traits and linear and nonlinear selection on multi-trait interactions. Our findings indicate that the creation of novel abiotic environments following invasion by habitat-forming species can modify selection on the phenotypes of native species.

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HULL FOULING ANO MOVEMENT PATl'l:HNS UI; I(H 'IO·ATI< **JNAI VI SI** 1, IN SAN FRANCISCO BAY: A PII.OT S'l'lll >Y

Zabin, Chela J. Smithsonian Environmental Research Center, Tiburon ('A ¹M¹J,>o l,111 l >11vldN1111, A,11111111 Bioinvasion Research & Policy Institute, Portland State University, Portland (>ll ('hl'IN W, lkc1w 11ı Smithsonian Environmental Research Center, Tihuron CA 94920 Andrew L. Chang, Ll11iVl'rNlty 111' California, Davis, Bodega Bay CA 94923 Mark Sytsma, Aquatic Bioinvasion Rescarch & Polky lnNlllull·, Portland State University, Portland OR Gregory M. Ruiz, Smithsonian Environmental Rcsl·a1-ch Ct•nkr, Edgewater, MD 21037

Oral Presentation

With over 200 nonindigenous species (NIS), San Francisco Bay has heen called "the most invaded aquatic ecosystem in North America." In 1995, Cohen & Carlton suggested that the hay might serve as a point of entry for non-native species which could suhsequently spread along the coast. The potential for spread via hull fouling seems high, given the thousands of recreational hoats in the hay, yet little was known ahout where or how frequently these hoats travel, or how heavily vessels are fouled. In 2007, we conducted a pilot study of six marinas in San Francisco Bay to gather preliminary data on the potential for recreational hoats to spread NIS. Our study included a questionnaire in which hoaters were asked to provide details regarding their hoats, hull hushandry practices and vessel use; a quantitative assessment of 72 hoat hulls using an underwater pole-mounted camera to determine the extent and hroad taxonomic composition of hiofouling; anda visual dockside assessments oflevel of fouling on 1265 vessels. Extent of fouling varied among marinas: mean cover ranged from 47.5% to 71%. Level of fouling was higher than that reported from similar surveys in Australia and Scotland. However, 76 percent of 221 hoaters who responded to the survey had not traveled outside the hay in the past year, and the most active hoats also had the least fouling. These preliminary data suggest that the risk of spread vía this vector is not well understood at least in part hecause the link hetween fouling levels and vector activity (hoat movements) needs further study. We are now engaged in an expanded study of San Francisco Bay marinas and nearhy small harbors.

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